

# **OSPAR CEMP Guidelines**

# Common Indicator: BH3 Extent of Physical Disturbance to Benthic Habitats

### OSPAR Agreement 2017-09<sup>1</sup>

This OSPAR biodiversity indicator is still under further development as a result of iteration and learning, alongside the incorporation of additional pressures data from other human activities causing seafloor disturbance. Version updates will be clearly indicated and be managed in a phased approach via ICG-COBAM through its expert groups and with the oversight and steer of BDC.

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<sup>1</sup> Update 2023.

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# CEMP Guidelines:

# Common Indicator Extent of Physical Disturbance to Benthic Habitats (BH3)

## 1. Introduction

This document provides a documentation of the methodology of the indicator 'Extent of Physical Disturbance to Benthic Habitats (BH3)'. The document is an OSPAR Guideline for the Coordinated Environmental Monitoring and Assessment Programme (CEMP). The CEMP guideline is published as OSPAR Agreement 2017-09, which was updated in 2022-2023.

#### 1.1. General introduction to the indicator

The aim of this indicator is to evaluate to what extent the sea floor and its associated ecology, species and habitats are being disturbed by human activities. The indicator is designed to assess all subtidal habitat types at a sub-regional level i.e. predominant habitats and MSFD special habitats, including OSPAR Threatened and/or Declining habitats (OSPAR Agreement 2008-6). It uses a combination of spatial analyses to extrapolate data and knowledge from local studies to larger areas, and therefore it is regarded as particularly useful for assessing large sea areas where currently only limited data are available.

Physical disturbance of the seabed by human activities such as fishing, sand extraction or offshore construction especially endangers habitats with larger and fragile species and species attached to the sea floor. In many regions of the OSPAR marine area, a shift in community composition has been reported where large and long-lived species have been replaced by small and fast-growing opportunistic species and scavengers that profit from disturbance and the availability of dead organisms (OSPAR, 2010; EEA, 2015). The impact of bottom trawling on the seafloor is considered to be the most widespread, as other activities are equally or more intense but spatially more limited.

The indicator will build upon two types of underlying information, i) the distribution and sensitivity of species and habitats (resilience and resistance), and ii) the distribution and intensity of human activities and pressures that cause physical disturbance, such as mobile bottom gear fisheries, sediment extraction and offshore construction. Data sources are analysed to calculate the potential disturbance to a given seafloor habitat, and the trends across assessment periods: decadal assessments for OSPAR Quality Status Report, 6-year for MSFD Article 8 reporting.

The indicator analysis is undertaken for all habitat types within each of the agreed assessments units per OSPAR region. To summarise the results per habitat type with each assessment, three habitats' classifications have been used: the Broadscale Habitat Types (BHT) under the EU Marine Strategy Framework Directive (MSFD), habitats listed under the OSPAR threatening and declining list, and the EUNIS (European nature Information System)<sup>2</sup> classification. Biogeography has been taken into account for the development of this indicator to assess variations of sensitivity when information was available.

<sup>&</sup>lt;sup>2</sup> Eunis classification: http://eunis.eea.europa.eu/habitats-code-browser.jsp

The methodology used have been thoroughly tested and reviewed by the OSPAR Benthic habitats expert Group, national experts and through focus workshops; it represents a realistic approach to assess the distribution of impacts across the regions based on current knowledge and using all evidence available. However, it is important to note that the strength of any assessment is dependent on the quality of the data, and this will in turn dictate the power and utility of the resultant information

The indicator method is under an ongoing programme of updates to incorporate latest improvement of evidence and scientific development, alongside additional data from other human activities and pressures not yet included under the current method. Therefore the following limitations should be noted:

- Distribution and proportionality of partial indicator pressure data used at this stage. Using data from >12m vessels, limits the dataset to large vessels and therefore will underestimate impact on those geographical areas where inshore fleets are based.
- At present pressure types are limited to seabed abrasion from fishing and commercial aggregate extraction, and does not include the other pressures which result in physical damage impacts from small vessels, or secondary impacts from dredging (e.g., smothering).
- Other activities causing physical disturbance, such as those associated with offshore structures, will be added in the next phase.
- Parts of the indicator calculations are still based on a classification of disturbance. Development of a
  quantitative approach to calibrate sensitivity values, using biological traits analysis and improvement
  of disturbance curves using data from other OSPAR indicators will be added in the next phase of
  indicator development.
- The indicator is not able to assess historical damage, which had caused the deterioration and modification of habitats in the past.
- At present a method to calculate the combined disturbance values from all activities occurring within a marine assessment unit has not been agreed. The approach will be developed in the next phase of indicator development, once additional disturbance data layers form other activities have been produced.

#### 1.2. Components

Biodiversity component: Benthic habitats

MSFD criterion & indicators (COM Dec 2017):

D6C2 – Primary: Spatial extent and distribution of physical disturbance pressures on the seabed

D6C3 — Primary: Spatial extent of each habitat type which is adversely affected, through change in its biotic and abiotic structure and its functions (e.g. through changes in species composition and their relative abundance, absence of particularly sensitive or fragile species or species providing a key function, size structure of species), by physical disturbance.

D6C5 — Primary: The extent of adverse effects from anthropogenic pressures on the condition of the habitat type, including alteration to its biotic and abiotic structure and its functions (e.g. its typical species composition and their relative abundance, absence of particularly sensitive or fragile species or species providing a key function, size structure of species), does not exceed a specified proportion of the natural extent of the habitat type in the assessment area.

OSPAR List of Threatened and/or Declining Species and Habitats:

**Table 1**: Habitats from the OSPAR List of Threatened and/or Declining Species and Habitats (OSPAR Agreement 2008-06) which could be assessed using this indicator

HABITATS
Carbonate mounds
Coral Gardens
Deep-sea sponge aggregations
Intertidal mudflats
Intertidal Mytilus edulis beds on mixed and sandy
sediments
Littoral chalk communities
Lophelia pertusa reefs
Maerl beds
Modiolus modiolus beds
<i>Ostrea edulis</i> beds
Sabellaria spinulosa reefs
Seamounts
Sea-pen and burrowing megafauna communities
Zostera beds

## 2. Monitoring

There are no specific monitoring requirements associated with this indicator, although the results on levels of disturbance and associated confidence can be used to target monitoring programmes or one-off surveys. It is expected that data from monitoring programmes, in particular those associated with other national and OSPAR indicators such as BH1 –Condition of Typical Species, and BH2b – Condition of Benthic habitat communities will be used to improve the evidence base and algorithms underpinning the metrics and concepts, and to calibrate and ground-truth the results.

#### 3. Data specifications

#### **3.1.** Data acquisition and preparation

Data are used from pre-existing sources (outlined below).

#### 3.2. List of data sources

*Fishing pressure data*: Aggregated gridded VMS data for surface abrasion and subsurface abrasion:

Fishing Data based on data from request to ICES 2021: https://iceslibrary.figshare.com/articles/report/OSPAR\_request\_on\_the\_production\_of\_spatial\_data\_l ayers\_of\_fishing\_intensity\_pressure/18639182

#### Commercial aggregate extraction pressure data:

Data sourced from OSPAR data call, 2021 with:

- Aggregated gridded AIS and EMS data commercially sensitive, not publicly available in raw format.
- Polygons of areas licensed for extraction: https://rconnect.cefas.co.uk/connect/#/apps/26/access https://miljoegis.mim.dk/cbkort?profile=miljoegis-raastofferhavet

#### Habitat data – EUNIS 2007 Levels 2 – 6:

Combined map, derived from *in-situ* survey data and offshore EMODnet outputs:

EMODnet Seafloor Habitats interactive map: https://www.emodnet-seabedhabitats.eu/about/euseamap-broad-scale-maps/

#### Benthic Species Data:

Marine Recorder public snapshot v52, published 05/08/2022; available from: https://jncc.gov.uk/our-work/marine-recorder/ and http://jncc.defra.gov.uk/page-1599)

Benthic species records sourced from OSPAR BH1/BH2b data call, 2021.

Benthic data sourced from OneBenthic database for aggregate extraction assessment to obtain industry data in areas licensed for extraction activity.

#### 3.3. Data reporting, handling and management

Pressure data and Habitat data have undergone QA/QC as part of the processing undertaken in their creation but are also subject to QA checks throughout the data processing steps of the indicator. Metadata is also completed throughout the process to document steps accurately. To align biological records with the QSR assessment period, benthic species sample data were only included from 2009 onwards.

#### 4. Assessment method

#### 4.1. Parameters and metrics

The final parameter/metric of this indicator is the extent and distribution of physical disturbance caused by anthropogenic pressures for each habitat type per assessment unit. Overall of the concept can be found in Figure 1.

The components of the analysis are:

- A composite habitat map showing the extent and distribution of habitats (based on observational and modelled data), including the mapped extent of any relevant features (e.g. records and distribution of particular species and biotopes like EUNIS Level 5 habitats or other biological characteristics). For the purpose of this assessment a biotope is defined as 'the combination of an abiotic habitat and its associated community of species (Connor *et al.* 2004). All habitat data were assessed at the greatest resolution possible, where habitat and sensitivity information were jointly available (range from EUNIS level 2 to Level 6)<sup>3</sup>;
- Tables relating benthic habitat types to habitat sensitivity scores based on their resistance and resilience (recoverability) (Tillin *et al.* 2010; BioConsult, 2013; Tillin & Tyler-Walters 2014a & 2014b; Maher and Alexander, 2016; Tyler-Walters *et al.*, 2018). The sensitivity is assessed at species, biotope resolutions (EUNIS Levels 2-4). In the absence of direct sensitivity assessments (e.g., Broadscale habitats) sensitivity values are aggregated following a precautionary principle to assign the most sensitive child biotope value to parent biotopes.
- Species sensitivity values are only assigned to the proportion of habitat polygons in which they occur, within a given c-square when the species sensitivity is higher than the sensitivity of the underlying habitat.
- Distribution and intensity of pressures causing physical damage. This analysis focussed on surface and sub-surface abrasion caused by bottom trawling (for fishing from vessels greater than 12m only) within 0.05° grid cells (c-squares) (JNCC, 2011; ICES, 2015; Church et al, 2016); and the physical disturbance of the seabed caused by marine aggregates extraction within 50 m x 50 m grid cells.
- Distribution of levels of disturbance per habitat type per year: Calculation of disturbance based on the intensity and duration of pressures and habitat sensitivity per pressure type.
- Please note that the pressures of abrasion (non-fisheries & non-extraction) and siltation are not currently included in the assessment, but will be incorporated in future developments of the indicator.

Data generated by the above elements are analysed using a step-wise approach to calculate the total area of different levels of disturbance, per habitat type for each assessment unit. The results are also used to calculate the levels of variability of fishing and extraction intensity, and trends in disturbance per year and across assessment periods (e.g., decadal QSR intervals and/or, 6-year MSFD cycles).

#### 4.2. Assessment criteria

• Assessment unit/scale (Temporal and spatial)

The spatial assessment of this indicator is aggregated at EUNIS Levels 2-6, and has been prepared by analysing the sensitivity and pressure data from habitats, biotopes, and species within habitat polygons, at the greatest resolution of available habitat and sensitivity data. For this assessment the OSPAR regions (II, III and IV) have been subdivided following marine assessment units where the indicator is common: RII Artic Waters (RIIAW). Southern North Sea (SNS), Central North Sea (CNS), Norwegian Trench (NT), Kattegat (Ka) Southern Celtic Sea (SCS), Northern Celtic Sea (NCS), English Channel (CH), Gulf of Biscay (GoB), North-Iberian Atlantic (NIA), South-Iberian Atlantic (SIA), and Gulf of Cadiz (GoC). It should be noted that some of the marine assessment units (NCS, SCS) are also including seafloor areas where the indicator is still considered candidate (Regions I and V). Additionally, the indicator has also been applied to an assessment unit wholly within Region V, the Atlantic projection (AP).

<sup>&</sup>lt;sup>3</sup> Eunis classification is currently being revised, but it has not been singed off. For the purposes of this assessment we have used the EUNIS classification version 2007-11

Three temporal scales are used:

- 1. Annually to calculate the distribution of disturbance within a year and,
- 2. Within a QSR assessment cycle (10 years) to calculate the total aggregated values for a whole cycle.
- 3. Within an MSFD cycle (6 years) to calculate the total aggregated values for a whole cycle.

The temporal assessment across a cycle of 10 and 6 years is calculated using the aggregation of pressure values to calculate disturbance. The method used to assess habitat and sensitivity data does not have a temporal scale associated with the spatial layers, although within the sensitivity results the resilience values are based mainly of the longevity of habitats and species as it is one of the key elements to assess their recoverability.

Baseline/ reference level (To be developed and discussed)

Environmental thresholds (To be developed and discussed)

#### 4.3. Spatial Analysis and trend analysis

The indicator method is based on a series of analytical steps to combine the distribution and intensity of physical damage pressures with the distribution and range of habitats and their sensitivities. The indicator will use an additive approach for future inclusion of multiple other pressures.



Figure 1. Conceptual overview of the indicator showing the different components of the indicator.

An overview of the concept is showing in Figure 1, illustrating the main results produced under each of steps of the analysis. A detailed description of each of the steps is described below:

#### Step 1: Extent and distribution of habitats

An important component of this indicator is the production of a composite habitat map showing the extent and distribution of habitat types and their associated sensitivities.

The OSPAR-scale habitat map integrated component habitat maps from both *in-situ* survey datasets and modelled MSFD Benthic Broad Habitat Types or EUNIS habitat data (in the absence of direct sample data). Habitats were mapped to the highest resolution of detail available, ranging from EUNIS Level 2 (physical habitats) to Level 6 (biological communities) via the following data sources and processes:

- 1. EUNIS habitat maps derived from surveys within the OSPAR Maritime Area extracted from EMODnet Seabed Habitats Data Portal.
- 2. Remaining gaps filled by EUSeaMap 2021 (Broad-scale predictive habitat maps) comprising:
  - EUSeaMap 2021 (Vasquez *et al.*, 2021) which covered all European sea basins where the EMODnet Geology seabed substrate map is available.
  - UKSeaMap 2018 (Manca & Lillis, 2020, in-prep.) a version of EUSeaMap that incorporated greater spatial resolution data available in United Kingdom waters, as revised by the Joint Nature Conservation Committee (JNCC). UKSeaMap 2018 was incorporated to ensure the highest resolution of data was used where available.

Please note that due errors in translation tables (at the time of assessment) between EUNIS 2007 and later versions (e.g., EUNIS 2019), newer versions of the EUNIS classification have not been used in this assessment (see Annex 1). All data included have been quality checked using a five-stage stepwise method to resolve GIS errors and overlapping habitat polygons to ensure that the most accurate polygon was represented in final map outputs.

Pre-processing conditions and rules for the combining of data are outlined in Annex 1.

For the production of the MSFD Broadscale Habitat types (BHT) translation tables were used to intersect the composite habitat map with EUSeaMap 2021 biological zone and substrate layers to facilitate translations between EUNIS and MSFD habitat classifications (please see Annex I for overview of translation process and supplementary data). As a final product for the presentation of the results a combined map with MSFD BHT across all the assessment units is produced.

#### Step 2: Assessing Sensitivity

The QSR 2023 introduces method changes that increase accuracy when analysing sensitivity, facilitating disturbance assessments at a biotope resolution (e.g., European Nature Information System (EUNIS) Level 6), a key improvement from the IA 2017 assessment (Moss, 2008; OSPAR, 2017a). Improved sensitivity assessments were achieved through the inclusion of MarESA sensitivity, a scientific approach to assessing habitat sensitivity (including habitat characterising species) to a range of pressures, based on those defined by the OSPAR Intercessional Correspondence Group on Cumulative Effects (ICG-C) (OSPAR, 2011 & 2014; Tyler-Walters et al., 2018). In instances where MarESA sensitivity information was not available for species and/or habitats, sensitivity was derived from the data used in the IA 2017, the Defra MB0102 Report No. 22, Task 3: Development of a Sensitivity Matrix (pressures-MCZ / MPA features) (hereafter referred to as MB0102) (Tillin et al., 2010; Tyler-Walters et al., 2018). When developing BH3 sensitivity layers, MarESA was prioritised over MB0102 sensitivity due to improved data quality and accuracy.

Due to the widespread nature of the BH3 assessment across the OSPAR Maritime Area, high-resolution EUNIS habitat data were not always available for some habitats, particularly, when mapping at a broadscale-habitat scale (e.g., EUNIS Levels 2 and 3). Therefore, automated methods based on the JNCC MarESA Aggregation were developed in Python 3.6 (Python Software Foundation, 2020), to aggregate biotope-resolution sensitivity data to all higher hierarchical tiers of the EUNIS classification (Last *et al.*, 2020). Sensitivity aggregations across tiers of the EUNIS hierarchy enabled child biotope sensitivity values to be assigned to parent biotopes on a precautionary basis, returning the highest sensitivities to assessed pressures (please see Python aggregation example in Annex 2). Wherever possible, biotope-scale assessments were used in disturbance calculations where a one-to-one relationship was available in habitat and sensitivity information (e.g., EUNIS Levels 4, 5 and 6) and aggregated scores used in the absence of direct assessments.

For full detail on the methods used for assigning sensitivity to habitats, please see Annex 2

#### Assigning sensitivity to species:

Species-specific resistance and resilience scores from MarESA and MB0102 were combined to maximise data coverage, increasing the total number of species with associated sensitivity assessments previously available in the IA 2017. Species-specific resistance and resilience scores for the associated pressures were combined into a single sensitivity score using the same process described for habitat sensitivity. In instances where multiple sensitivity scores were available for the same species, scores with the highest confidence were assigned, if confidence assessments were equal, then the most precautionary values were used.

Species and habitat sensitivity data were combined using gridded approaches to allocate species sensitivity to the proportions of habitat polygons within the grid cell (resolution relevant to the assessed pressure), when the underlying habitat was less sensitive. The introduction of the precautionary approach, which only considers the highest sensitivity value (between species and habitats) built on work in the IA 2017 to ensure that sensitivity from species was representative of the location the species was recorded. Expert review via the OSPAR framework highlighted that less sensitive species, capable of withstanding pressure-causing events were potentially misrepresenting the sensitivity of underlying habitat polygons and therefore, impacted habitats; the QSR 2023 improves on this method through the aforementioned change in how species records were treated in assessments.

For full detail on the methods used for assigning sensitivity to species, please see Annex 3.

#### Step 3.1: Pressure assessments: VMS / bottom-contact fishing

Step 3 of the QSR 2023 BH3 assessment involved creating a single layer that quantified annual and aggregated surface and subsurface abrasion pressure for the two assessment periods (2009 to 2020 for QSR and 2016 to 2020 for MSFD). Fishing pressure data ranging from 2009 to 2020 (2020 being the newest data at the time of this assessment) were obtained from ICES (OSPAR, 2021). Data were obtained from ICES via an OSPAR data call, collating VMS and logbook data from ICES member countries to develop spatial data layers representative of fishing intensity / pressure within the OSPAR Maritime Area (ICES, 2021). Between 2009 and December 31<sup>st</sup>, 2011, VMS data were only available for fishing vessels greater than 15 m in length; following changes in the Common Fisheries Policy (EU Council Regulation No. 44 / 2012), from January 1<sup>st</sup>, 2012, onward, datasets contained VMS from vessels over 12m in length.

The ICES data layers contained the total annual swept-area and swept-area ratio (SAR) values for both surface (< 2 cm penetration depth of the gear components) and subsurface ( $\geq$  2 cm penetration depth of the gear

components) fishing pressure. Both swept area and SAR were calculated using standardised grids, known as c-squares (0.05° x 0.05° grid cell), the spatial resolution adopted by ICES (Rees, 2003; ICES, 2021). Swept-area is a multiplication of the width of the gear in contact with the seabed by the average vessel speed and the time fished per unit area (c-square) per year. The SAR (representative of fishing intensity) is the swept-area divided by the total surface area of the c-square.

To ensure that assessments were representative of the actual fishing gears in contact with the seafloor, estimates of total annual surface and subsurface SAR values within each c-square were informed by parameters (e.g., gear width) associated with relevant bottom-contacting métiers (Eigaard *et al.*, 2015; Church *et al.*, 2016; ICES, 2021). A métier refers to a group of fishing operations targeting a specific assemblage of species, using a specific gear, during a precise period of the year and / or within the specific area (Deporte, *et al.*, 2012). For further method details on the creation of the fishing pressure layers, refer to ICES (2021).

When analysing the ICES VMS data available for the QSR 2023 assessment the following caveats should be noted:

- The data assumed fishing intensity to be homogeneous over each c-square, which may have under / overestimated activity, should fishing be constrained to discrete areas within the cell.
- VMS data for vessels less than 12 m in length were not available at the time of assessment. Therefore, inshore areas, or those where vessels below 12 m in length may be poorly represented.
- VMS data from Portugal, Iceland and Norway were not included in assessments as the submitted data did not pass ICES quality checks, therefore, some fleet activities may be absent and / or underrepresented.
- Fishing pressure (SAR, swept-area ratio) depended on the spatial resolution of the fishing pressure data (0.05° × 0.05° grid cells in this instance). It should be noted that due to the curvature of the Earth not all c-squares have the same area in km2.
- VMS data supplied for the OSPAR Maritime Area did not include the entirety of the Kattegat assessment unit (Ise Fjord, Roskilde Fjord and Øresund strait areas).

#### Analysis of fishing pressure for individual years:

Surface and subsurface SAR values were categorised with an intensity scale ranging from 'none' to 'very high' (OSPAR, 2017b), where a cell has been swept more than 300% or three times per year. The intensity scale was based on the results of Schroeder *et al.* (2008) indicating that a SAR of 1 was considered to have a high impact on species abundance. SAR values between 0 and 1 were split into three categories based on the results of calculations of van Loon (2015), supported by van Loon (2018), suggesting a significant biological response between SAR values of 0.15 to 1. Annual assessments of pressure were conducted on categorised SAR values, as informed by literature, and likely impacts on species abundance.

To assess fishing pressure over the QSR 2023 assessment period, aggregated pressure layers were created, combining annual pressure layers into a single dataset for use in disturbance assessments. Aggregated pressure data were cleaned prior to assessing disturbance, ensuring that c-squares without fishing activity reported in the ICES data were not erroneously analysed as 0 pressure.

The method for assessing temporal fishing variability, as agreed by OSPAR in the IA 2017 was implemented in the QSR 2023 (Annex 4). The range of SAR categories observed across the time series was calculated for each c-square, indicating distinction between areas where fishing intensity was at 'Consistent' levels across years, from those where fishing intensity levels fluctuated. C-squares were considered 'Variable' if a range of three or more SAR categories was observed throughout the time series. The use of three or more SAR categories to denote variance originated in the IA 2017 and was based on expert judgement. C-squares that had a variance range of three or more SAR categories were used to indicate areas of opportunistic fishing, potentially new areas being explored for fishing or areas which were not used consistently.

To produce a layer showing the aggregated surface and subsurface pressures that accounted for variations in fishing pressure across years, the following method was used:

- For cells with low variability (i.e., a range of less than three SAR categories), the mean of SAR values across all years with available data was calculated (areas without SAR reported were not analysed as 0 pressure).
- For cells with high variability (i.e., range of three or more SAR categories), the highest SAR value across all years was selected following a precautionary approach to represent the most damaging levels of fishing to benthic habitats (OSPAR, 2017).

#### Step 3.2: Pressure assessments: Commercial aggregate extraction

Following consultation between the OSPAR Environmental Impacts of Human Activities Committee (EIHA) and Biodiversity Committee (BDC), an assessment of commercial aggregate extraction was selected as the next activity to be analysed by BH3, following previous assessments of fisheries in the Intermediate Assessment 2017. The QSR 2023 is the first assessment on the physical disturbance of benthic habitats and seafloor integrity associated with commercial aggregate extraction via the BH3 indicator. Extraction data analysed were collated via a joint EIHA and BDC data call, circulated in June 2021. The data call aimed to facilitate standardised and regionally comparable assessments of physical disturbance associated with aggregate extraction on benthic habitats, within the OSPAR Maritime Area. Data were requested from all OSPAR Regions in the formats of:

- 1. Licensed extraction areas and.
- 2. Gridded extraction data, as either:
  - 2a. total volume dredged, per licensed extraction area/per grid cell, and / or;
  - 2b. extraction duration in units of time per grid cell as gridded spatial data, indicative of the activity intensity, including both vessel Automatic Identification System (AIS) and Electronic Monitoring System (EMS) data.
- 3. Confirmation of OSPAR Contracting Parties where aggregate extraction activity was known not to occur.

To align with wider North-East Atlantic-scale assessments of aggregate extraction, such as those conducted by the ICES Working Group on the Effects of Extraction of Marine Sediments on the Marine Ecosystem (ICES-WGEXT), footprint data were analysed using a standardised 50 m x 50 m grid format. Grids of 50 m x 50 m are beneficial for assessing aggregate extraction data as they equate to the frequency of vessel EMS / AIS pings (typically every 20–30 seconds) (ICES, 2019a). Additionally, the OSPAR QSR presented a temporal assessment of pressure, which required annual gridded data to spatially align; the grids aligned with parameters derived from European Environment Agency Reference Grids and Infrastructure for Spatial Information in Europe (INSPIRE) geographical grid systems, which previously facilitated standardised reporting on progress and the implementation of the Marine Strategy Framework Directive and Article 17 of the Habitats Directive (EEA, 2017).

Datasets, such as polygons of areas licensed for extraction were not viable for use in assessments of disturbance, as it was not possible to know where within a given area was dredged. Therefore, license area polygons were summarised by the sensitivity of species and habitats within relevant assessment units, and not assessed for disturbance. Disturbance calculations were solely undertaken in areas (UK & DK) where

footprint pressure data were available. UK and Danish footprint data were analysed by calculating SAR; UK SAR were calculated using the total dredge time per grid cell and Danish SAR values were derived from exact polylines of vessel tracklines. Please note, to safeguard commercially sensitive information, raw extraction duration and polyline data from the United Kingdom and Denmark, respectively, were assigned pressure categories prior to disturbance assessments.

For full detail on calculations in both locations, including equations and component informations, please see Annex 5.

#### Aggregated Extraction Pressure Maps to Represent Pressure Across Multiple Years

An aggregated extraction pressure map representative of the assessment periods 2009 to 2020 (QSR assessment period) and 2016 to 2020 (MSFD assessment period) was created based on the BH3 methodology. Due to the temporal range of the two respective datasets (United Kingdom: 2009 to 2020, and Denmark: 2015 to 2020), data from the United Kingdom alone was used to calculate the QSR aggregated pressure values. Data from both the United Kingdom and Denmark were used to calculate the MSFD aggregated pressure values. To assess extraction pressure from the United Kingdom and Denmark across multiple years, the range of pressure categories observed across the time series was calculated for each grid cell. Cells were considered 'Variable' if a range of three or more categories was observed throughout the time series and 'Non-variable' if pressure categories had a range of less than three. To represent an aggregated pressure value for the time series, cells with 'Non-variable' pressure used the mean SAR value across all years to assign a BH3 pressure category. Cells with 'Variable' pressure used the maximum SAR value from all years to assign a BH3 pressure category. However, in contrast to the assessment of fishing pressure, grid cells with no aggregate extraction present in a given year, where extraction activity was present in other years, were treated as 0 pressure. This specific distinction of 0 pressure was made as commercial aggregate extraction is a licensed activity and, where a Contracting Party submitted data, there was high confidence that the data accounted for all commercial aggregate extraction activity within the Contracting Party's EEZ. Upon categorising final SAR values representative of pressure across multiple years, all data indicative of duration extracting, and uncategorised SAR were removed prior to further analyses to safeguard commercially sensitive information.

#### Step 4.1: Calculation of disturbance

This step of the assessment is calculated by creating a spatial layer that quantified disturbance to species and habitats within the OSPAR Maritime Area. Sensitivity (outputs of Step 2) and pressure (outputs of Step 3) maps were spatially intersected via Environmental Systems Research Institute (ESRI) ArcGIS software (ESRI, 2012). Potential surface and subsurface disturbance were calculated on the intersect output layer by combining sensitivity and pressure values, producing nine categories of disturbance (1–9, where 9 was the maximum risk of disturbance possible). The matrix was created from previous studies that analysed the impacts of pressures on sensitive species and habitats when applied at different intensities (Schroeder *et al.*, 2008; Rondinini, 2010; BioConsult, 2013; van Loon *et al*, 2018). In instances where pressure data intersected areas without sensitivity information (due to a lack of EUNIS habitat data or sensitivity assessment), outputs were classified as 'Unassessed Disturbance'.

Annual and aggregated (2009 to 2020; 2016 to 2020 assessment periods) potential surface and subsurface disturbance values were calculated from the corresponding annual and aggregated pressure categories. The highest surface and subsurface disturbance categories were presented as the final disturbance category for each assessment period, following a precautionary principle. Disturbance categories were summarised into four groups ('Zero' = disturbance category 0, 'Low' = disturbance categories 1-4, 'Moderate' = disturbance categories 5-7, and 'High' = disturbance categories 8 and 9) derived from the 0-9 disturbance scale (Schroeder et al., 2008; OSPAR, 2017). Please note, these groupings are not representative of thresholds and should be used for comparative interpretations of disturbance outputs across the OSPAR Maritime Area only. Disturbance category 0 and therefore disturbance group 'Zero' were not included in the BH3 extraction assessment as only extraction pressure data from Denmark and the United Kingdom were available for full disturbance analyses at the time of assessment. As extraction data from other Contracting Parties was not available for disturbance analyses at the time of assessment unit with no extraction footprint data.

Detailed information on the analysis can be found in Annex 6.

#### Step 5: EUNIS to MSFD Benthic Broad Habitat Type (BHT) Translation

To maximise usability of assessment results for Contracting Parties that report against Article 8 of the MSFD, Step 5 assigned disturbance outputs based on EUNIS habitat codes to the appropriate BBHT in the MSFD classification system. A translation table was created by habitat classification experts at JNCC and EMODnet to facilitate correlation between EUNIS habitat and BHTs. In some instances, translations required combinations of EUNIS code, biological zone and / or substrate information to correctly assign BHT where EUNIS habitats contained or partially overlapped with multiple BHTs. Biological zone and substrate information was obtained from a spatial intersect of the disturbance layer with EUSeaMap 2021 (Vasquez *et al.*, 2021) using ArcGIS v.10.1. EUNIS habitats that couldn't be assigned MSFD translations (e.g., lacking substrate information) were designated "No EUNIS to BHT translation".

#### Step 6: Assessment of OSPAR Threatened and / or Declining Habitats

Disturbance from bottom contacting fishing in OSPAR Threatened and / or Declining Habitats (OSPAR, 2008 & 2019) was assessed using the OSPAR Habitats in the North-East Atlantic Ocean - 2020 Polygons layer (EMODnet, 2020). The layer is a compilation of OSPAR Threatened and / or Declining Habitats data submitted by OSPAR Contracting Parties and is a separate data product to the composite habitat map. Sensitivity of habitats were assigned using habitat definition EUNIS codes and corresponding MarESA sensitivity assessments. In instances where habitats had multiple biotope codes, the maximum sensitivity was assigned following a precautionary approach.

For habitats without MarESA assessments (e.g., carbonate mounds, coral gardens, and seamounts) sensitivity was assigned following Tillin & Tyler-Walters (2010; coral carbonate mounds, coral gardens, and seamounts). For habitats that were present in common Indicator Assessment units, habitat definition EUNIS codes and assessed sensitivity are summarised in **Table 10**. Disturbance in OSPAR Threatened and / or Declining Habitats was calculated using the aggregated fishing pressure spatial layers, developed in Step 3 (assessment period 2009 to 2020). Results were summarised grouping disturbance values as 'Zero', 'Low' (1-4), 'Moderate' (5-7), and 'High' (8-9), following the same approach as for non-OSPAR Threatened and / or Declining Habitats.

#### Step 7: Confidence assessments<sup>4</sup>

To spatially represent confidence in the data, a numeric method of calculating confidence was adapted from an internal OSPAR method previously developed by the Environmental Impacts of Human Activities Committee (EIHA). The method combines relative measures of confidence on a scale from 0–1, where there was a difference in confidence between categories or classes used in a data layer.

A numerical score (0.33, 0.66 or 1) was assigned to each of the different attributes used to create the sensitivity layer. A high confidence score was given a numeric value of 1, medium 0.66 and low 0.33. The different methods used to create the sensitivity layer were taken in turn and a numeric confidence score was assigned to each of the attributes: confidence based on underlying data; confidence within data source (such as MESH confidence for habitats); and confidence in the sensitivity of the habitat to a pressure.

Further technical guidance on each of the spatial analysis and analytical steps can be found in the set of annexes accompanying this document.

## 5. Change Management

Responsibility for this CEMP guideline and follow up of indicator assessments falls under the OSPAR Biodiversity Committee, the work is undertaken by the OSPAR Benthic Habitats Expert Group (OBHEG) which provides input to ICG-COBAM.

The indicator as described in this document remains under methodical development to improve the outputs, specifically in a number of areas:

- the lack of data from small vessel/inshore fisheries and other activities causing physical damage across regions (e.g. offshore construction);
- review of the biogeographical assessment units and environmental data;
- review of the sensitivity and disturbance methods
- development of reference conditions;
- a better understanding of the spatial and temporal impacts of different fishing gear types.

<sup>&</sup>lt;sup>4</sup> Please note the calculation of confidence scores will be one the last tasks of the assessments, and only be done once the results and data sources have been reviewed.

#### 6. References

#### **Bottom-Contact Fishing Assessment:**

BioConsult, 2013. Seafloor integrity - Physical damage, having regard to substrate characteristics (Descriptor 6). A conceptual approach for the assessment of indicator 6.1.2: 'Extent of the seafloor significantly affected by human activities for the different substrate types'. Report within the R & D project 'Compilation and assessment of selected anthropogenic pressures in the context of the Marine Strategy Framework Directive', UFOPLAN 3710 25 206.

Castle L., Lillis H., Duncan G. & Manca E., 2021. Method for creating a EUNIS level 3 seabed habitat map integrating fine- and broad-scale maps for the North-East Atlantic. JNCC report in Prep.

Church N.J., Carter A.J., Tobin D., Edwards D., Eassom A., Cameron A., Johnson G.E., Robson, L.M. & Webb K.E., 2016. JNCC Recommended Pressure Mapping Methodology 1. Abrasion: Methods paper for creating a geo-data layer for the pressure 'Physical Damage (Reversible Change) - Penetration and / or disturbance of the substrate below the surface of the seabed, including abrasion'. JNCC report No. 515, JNCC, Peterborough.

Collie, J. S., Hall., S. J., Kaiser, M. J., and Poiner, I. R. 2001. A quantitative analysis of fishing impacts on shelf-sea benthos. *Journal of Animal Ecology*, 69(5); 7785-798

Defra, 2015. Validating an Activity-Pressure Matrix. *Report R.2435*.

Deporte, N., Ulrich, C., Mahévas, S., Demanèche, S., Bastardie, F., 2012. Regional métier definition: a comparative investigation of statistical methods using a workflow applied to international otter trawl fisheries in the North Sea. *ICES Journal of Marine Science*, Volume 69, Issue 2, March 2012, Pages 331–342.

Eigaard, O.R., Bastardie, F., Breen, M., Dinesen, G.E., Hintzen, N.T., Laffargue, P., Mortensen, L.O., Rasmus Nielsen, J., Nilsson, H.C., O'Neill, F.G., Polet, H., Reid, D.G., Sala, A., Sköld, M., Smith, C., Sørensen, T.K., Tully, O., Zengin, M., Rijnsdorp A.D., 2016. Estimating seabed pressure from demersal trawls, seines, and dredges based on gear design and dimensions. *ICES Journal of Marine Science*, Volume 73, Issue suppl\_1, January 2016, Pages i27–i43.

Ellwood, H. 2014. Creating a EUNIS level 3 seabed habitat map integrating data originating from maps from field surveys and the EUSeaMap model. JNCC

2010 MESH Confidence Assessment. [Online] Available at: http://www.emodnet-seabedhabitats.eu/default.aspx?page=1635 (Accessed: 01/12/2021).

EMODnet, 2020. OSPAR Habitats in the North-East Atlantic Ocean - 2020 Polygons [Online] Available at: http://www.emodnet-seabedhabitats.eu/access-data/download-data/?linkid=ospar\_2020\_poly (Accessed: 01/12/2021).

EMODnet, 2021. Seabed Habitats. [Online] Available at: https://emodnet.ec.europa.eu/en/seabed-habitats (Accessed: 01/12/2021).

EMODnet Bathymetry Consortium. 2020. EMODnet Digital Bathymetry (DTM). Available at: https://portal.emodnet-bathymetry.eu/?menu=19 (Accessed 09/08/2022).

Eno, N.C., Frid, C. L. J., Hall, K., Ramsay, K., Sharp, R. A. M., Brazier, D. P., Hearn, S., Dernie, K. M., Robinson, K. A, Paramor, O. A. L., and Robinson, L. A. 2013. Assessing the sensitivity of habitats to fishing: from seabed maps to sensitivity maps. *Journal of Fish Biology*, 83, 826-846

ESRI, 2012. ArcGIS Release 10.1. Redlands, CA.

European Environment Agency, (EEA), 2017. EEA marine assessment grid, Jan. 2017. European EnvironmentAgencyGeospatialDataCatalogue.[Online]Availableat:

https://sdi.eea.europa.eu/catalogue/srv/eng/catalog.search#/metadata/84d1f816-1913-45b1-94b7-a5721a18296c (Accessed 08/11/2021).

European Environment Agency, (EEA), 2021. EUNIS Habitat Classification. [Online] Available at: https://www.eea.europa.eu/data-and-maps/data/eunis-habitat-classification-1. (Accessed: 08/11/2021).

Garrard, S.M., Perry, F. & Tyler-Walters, H., 2019. Discrete Lophelia pertusa colonies on Atlantic mid bathyal rock and other hard substrata. In Tyler-Walters H. and Hiscock K. *Marine Life Information Network: Biology and Sensitivity Key Information Reviews, Plymouth Marine Biological Association of the United Kingdom.* 

Garrard, S.M., Perry, F. & Tyler-Walters, H., 2020. Discrete Lophelia pertusa colonies on Atlantic upper bathyal rock and other hard substrata. In Tyler-Walters H. and Hiscock K. *Marine Life Information Network: Biology and Sensitivity Key Information Reviews, Plymouth Marine Biological Association of the United Kingdom.* 

Gerritsen, H., Minto, C. and Lordan, C., 2013. How much of the seabed is impacted by mobile fishing gear? Absolute estimates from Vessel Monitoring System (VMS) point data. ICES Journal of Marine Science, 70(3), pp.523-531.

Holling C.S., 1973. Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics*, 4(1), 1-23.

ICES, 2015. Report of the Working Group on Spatial Fisheries Data (WGSFD).

ICES, 2021. OSPAR request on the production of spatial data layers of fishing intensity / pressure. *ICES Technical service*.

JNCC, 2011. Review of methods for mapping anthropogenic pressures in UK waters in support of the Marine Biodiversity Monitoring R&D Programme. Briefing paper to UKMMAS evidence groups. Presented 06/10/2011.

Lambert, G. I., Jennings, S., Kaiser, M. J., Davies, T. W., and Hiddink, J. G., 2014. Quantifying recovery rates and resilience of seabed habitats impacted by bottom fishing. Journal of Applied Ecology, 51(5); 1326-1336.

Last, E.K., Matear, L. & Robson, L.M., 2020. Developing a method for broadscale & feature-level sensitivity assessments: the MarESA aggregation. JNCC Report No. 662, JNCC, Peterborough, ISSN 0963-8091.

Last, E.K., Ferguson, M. & Robson, L.M. 2019a. Mixed coral assemblage on Atlantic mid bathyal Lophelia pertusa reef framework (biogenic structure). In Tyler-Walters H. Marine Life Information Network: Biology and Sensitivity Key Information Reviews. *Plymouth Marine Biological Association of the United Kingdom*.

Last, E.K., Ferguson, M. & Robson, L.M. 2019b. Mixed coral assemblage on Atlantic upper bathyal Lophelia pertusa reef framework (biogenic structure). In Tyler-Walters H. Marine Life Information Network: Biology and Sensitivity Key Information Reviews. *Plymouth Marine Biological Association of the United Kingdom*.

Manca, E. and Lillis H., 2022. 2019 Update to UKSeaMap – a broad-scale seabed habitat map for the UK. *In prep.* 

Moss, D., 2008. EUNIS Habitat classification - a guide for users. *European Topic Centre on Biological Diversity*. [Online] Available at: <u>https://www.eea.europa.eu/data-and-maps/data/eunis-habitat-classification</u> (Accessed 03/02/2022)

OSPAR Commission, 2008. OSPAR List of Threatened and / or Declining Species and Habitats (OSPAR Agreement 2008-06) [Online] Available at: https://www.ospar.org/documents?d=32794.

OSPAR Commission, 2011. Pressure list and descriptions. Paper to ICG-COBAM 11/8/1 Add.1-E (amended version 25th March 2011) presented by ICG-Cumulative Effects. OSPAR Commission, London.

OSPAR Commission, 2014. OSPAR Joint Assessment and Monitoring Programme (JAMP) 2014-2023.

OSPAR Commission, 2017a. OSPAR Intermediate Assessment 2017. OSPAR Commission. London.

OSPAR Commission, 2017b. OSPAR Coordinated Environmental Monitoring Programme (CEMP) Guidelines. Common Indicator: BH3 Extent of Physical damage to predominant and special habitats (https://www.ospar.org/documents?v=37641).

OSPAR Commission, 2018. OSPAR Coordinated Environmental Monitoring Programme (CEMP) Guidelines. Common indicator: Condition of benthic habitat communities (BH2) – common approach.

OSPAR Commission, 2019. QSR 2023 Guidance Document. OSPAR Agreement 2019-02.

OSPAR Commission, 2022. List of Threatened and / or Declining Species & Habitats; Habitats [Online] Available at: https://www.ospar.org/work-areas/bdc/species-habitats/list-of-threatened-declining-species-habitats/habitats (Accessed 01/02/2022)

Pebesma, E., 2018. Simple Features for R: Standardized Support for Spatial Vector Data. The R Journal 10 (1), pp. 439-446.

Python Software Foundation, 2020. Python Language Reference, version 3.7.11.

R Core Team, 2019. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

R Core Team, 2020. R: A language and environment for statistical computing. *R Foundation for Statistical Computing, Vienna, Austria.* 

R Core Team, 2021. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Robinson, L.A., Rogers S. & Frid, C.L.J., 2008. A marine assessment and monitoring framework for application by UKMMAS and OSPAR - Assessment of Pressures and Impacts. Phase II: Application for regional assessments. JNCC Contract No: C-08-0007-0027. UKMMAS, 2010. Charting Progress 2.

Robson, L.M., Fincham, J., Peckett, F.J., Frost, N., Jackson, C., Carter, A.J. & Matear, L. 2018. UK Marine Pressures-Activities Database "PAD": Methods Report. *JNCC Report No. 624*, JNCC, Peterborough, ISSN 0963-8091.

Rondinini, C. 2010. Meeting the MPA network design principles of representation and adequacy: developing species-area curves for habitats. *JNCC Report No. 439*. JNCC, Peterborough

Schroeder, A., Gutow, L., & Gusky, M., 2008. FishPact. Auswirkungen von Grundschleppnetzfischereien sowie von Sand- und Kiesabbauvorhaben auf die Meeresbodenstruktur und das Benthos in den Schutzgebieten der deutschen AWZ der Nordsee (MAR 36032/15). Report for the Bundesamt für Naturschutz.

Serrano, A., de la Torrientea A., Punzóna, A., Blancoa, M., Bellas, J., Durán-Muñoz, P., Murillo, F.J., Sacau, M., García-Alegrea, A., Antolíneza, A., Elliott, S., Guerine, L., Vina-Herbón, C.V., Marra, S., González-Irustaa, J.M., 2022. Sentinels of Seabed (SoS) indicator: Assessing benthic habitats condition using typical and sensitive species. Ecological Indicators, 140, 108979.

Tillin, H.M., Hull, S.C. & Tyler-Walters, H., 2010. Development of a Sensitivity Matrix (pressures-MCZ / MPA features). Defra Contract No. MB0102 Task 3A, Report No. 22.

Tillin, H., Tyler-Walters, H., 2014a. Assessing the sensitivity of subtidal sedimentary habitats to pressures associated with marine activities. Phase 1 Report: Rationale and proposed ecological groupings for Level 5 biotopes against which sensitivity assessments would be best undertaken. JNCC Report No. 512A, 68 pp.

Tillin, H. & Tyler-Walters, H., 2014b. Assessing the sensitivity of subtidal sedimentary habitats to pressures associated with marine activities. Phase 2 Report – Literature review and sensitivity assessments for ecological groups for circalittoral and offshore Level 5 biotopes. JNCC Report No. 512B, 260 pp.

Tillin, H.M. & Tyler-Walters, H., 2015. Finalised list of definitions of pressures and benchmarks for sensitivity assessment. 7-9.

Tyler-Walters, H., Tillin, H.M., d'Avack, E.A.S., Perry, F. & Stamp, T., 2018. Marine Evidence\_based Sensitivity Assessment (MarESA) – A Guide. Plymouth: Marine Biological Association.

Sanders, M. J., and Morgan, A. J., 1976. Fishing power, fishing effort, density, fishing intensity and fishing mortality. *ICES Journal of Marine Sciences*, 37(1), 36-40.

Van Denderen, P. D., Bolam, S. G., Hiddink, J. G., Jennings, S., Kenny, A., Rijnsdorp, A. D., and van Kooten, T., 2015. Similar effects of bottom trawling an natural disturbance on composition and function of benthic communities across habitats. *Marine Ecology Progress Series*, 341, 31-43.

Van Loon, W.M.G.M., Boon, A.R., Gittenberger, A., Walvoort, D.J.J., Lavaleye, M., Duineveld, G.C.A., Verschoor, A.J., 2015. Application of the Benthic Ecosystem Quality Index 2 to benthos in Dutch transitional and coastal waters, Journal of Sea Research, Volume 103, 1-13.

Van Loon, W.M.G.M., Walvoort, D.J., Van Hoey, G., Vina-Herbon, C., Blandon, A., Pesch, R., Schmitt, P., Scholle, J., Heyer, K., Lavaleye, M. and Phillips, G., 2018. A regional benthic fauna assessment method for the Southern North Sea using Margalef diversity and reference value modelling. Ecological Indicators, 89, 667-679.

Vasquez, M., Allen, H., Manca, E., Castle, L., Lillis, H., Agnesi, S., Al Hamdani, Z., Annunziatellis, A., Askew, N., Bekkby, T., Bentes, L., Doncheva, V., Drakopoulou, V., Duncan, G., Gonçalves, J., Inghilesi, R., Laamanen, L., Loukaidi, V., Martin, S., McGrath, F., Mo, G., Monteiro, P., Muresan, M., Nikilova, C., O'Keeffe, E., Pesch, R., Pinder, J., Populus, J., Ridgeway, A., Sakellariou, D., Teaca, A., Tempera, F., Todorova, V., Tunesi, L. & Virtanen, E., 2021. EUSeaMap 2021, A European broad-scale seabed habitat map, Technical Report.

Wickham et al., 2019. Welcome to the tidyverse. Journal of Open-Source Software, 4(43), 1686.

#### **Commercial Aggregate Extraction Assessment:**

BioConsult (2013). Seafloor integrity - Physical damage, having regard to substrate characteristics (Descriptor 6). A conceptual approach for the assessment of indicator 6.1.2: 'Extent of the seafloor significantly affected by human activities for the different substrate types'. Report within the R & D project 'Compilation and assessment of selected anthropogenic pressures in the context of the Marine Strategy Framework Directive', UFOPLAN 3710 25 206.

Birchenough, S.N.R., Boyd, S.E., Vanstaen, K., Coggan, R.A. & Limpenny, D.L. (2010). Mapping an aggregate extraction site off the Eastern English Channel: A methodology in support of monitoring and management. *Estuarine, Coastal and Shelf Science*. Volume 87, Issue 3, 30 April 2010, Pages 420-430.

Bole, A., Wall, A. & Norris, A. (2014). Chapter 5 - Automatic Identification System (AIS). *Radar and Target Tracking for Professional Mariners, Yachtsmen and Users of Marine Radar*. 3. 255-275.

Boyd, S.E. & Rees, H.L. (2003). An examination of the spatial scale of impact on the marine benthos arising from marine aggregate extraction in the central English Channel. *Estuarine, Coastal and Shelf Science*. Volume 57, Issues 1–2, May 2003, Pages 1-16.

Boyd, S.E., Limpenny, D.S., Rees, H.L., Cooper, K.M. & Campbell, S. (2003). Preliminary observations of the effects of dredging intensity on the re-colonisation of dredged sediments off the southeast coast of England (Area 222). Estuarine, Coastal and Shelf Science. Volume 57, Issues 1–2, May 2003, Pages 209-22.

British Marine Aggregate Producers Association (BMAPA) & The Crown Estate (TCE), 2010 to 2021. Area involved reports – 12<sup>th</sup> to the 23<sup>rd</sup> annual report. [Online] Available at: <u>https://bmapa.org/downloads/reference.php</u> (Accessed September 2022)

British Marine Aggregate Producers Association (BMAPA) & The Crown Estate (TCE), (2010). MarineAggregateTerminology-AGlossary.[Online]Availableat:https://bmapa.org/documents/BMAPAGlossary.pdf (Accessed April 2021)

British Marine Aggregate Producers Association (BMAPA) & The Crown Estate (TCE). (2017). The impacts of marine aggregate dredging. *Good Practice Guidance: Extraction by Dredging of Aggregates from England's Seabed*. 9-10. [Online] Available at: <u>https://www.bmapa.org/documents/BMAPA\_TCE\_Good\_Practice\_Guidance\_04.2017.pdf</u> (Accessed April 2021)

Castle L., Lillis H., Duncan G. & Manca E. (2021). Method for creating a EUNIS level 3 seabed habitat map integrating fine- and broad-scale maps for the North-East Atlantic. JNCC report in Prep.

Church N.J., Carter A.J., Tobin D., Edwards D., Eassom A., Cameron A., Johnson G.E., Robson, L.M. & Webb K.E. (2016). JNCC Recommended Pressure Mapping Methodology 1. Abrasion: Methods paper for creating a geo-data layer for the pressure 'Physical Damage (Reversible Change) - Penetration and/or disturbance of the substrate below the surface of the seabed, including abrasion'. JNCC report No. 515, JNCC, Peterborough.

Connor, D, W., Allen, J, H., Golding, N., Howell, K, L., Lieberknecht, L, M., Northern, K, O. & Reker, J, B. (2004). The Marine Habitat Classification for Britain and Ireland Version 04.05. JNCC, Peterborough ISBN 1 861 07561 8. [Online] <u>http://jncc.defra.gov.uk/pdf/04\_05\_introduction.pdf</u> (Accessed April 2021) Cooper K., Boyd S., Eggleton J., Limpenny D., Rees H. & Vanstaen K., (2007). Recovery of the seabed following marine aggregate dredging on the Hastings Shingle Bank off the southeast coast of England. *Estuarine Coastal and Shelf Science*, 75(4), 547-558.

Cooper K.M., Eggleton J.D., Vize S.J., Vanstaen K., Smith R., Boyd S.E., Ware S., Morris C.D., Curtis, M. I., Limpenny D.S. & Meadows W.J., (2005). Assessment of the re-habilitation of the seabed following marine aggregate dredging-part II. *Cefas Science Series Technical Report No. 130*. Cefas Lowestoft. 82.

Defra, (2015). Validating an Activity-Pressure Matrix. *Report R.2435*. [Online] Available at: http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Compl eted=0&ProjectID=19471 (Accessed April 2022).

Desprez, M. (2000). Physical and biological impact of marine aggregate extraction along the French coast of the Eastern English Channel: short and long-term post-dredging restoration. *ICES Journal of Marine Science*, 57: 1428–1438.

Desprez, M., Stolk, A., & Cooper, K.M. (2022). Marine aggregate extraction and the Marine Strategy Framework Directive: A review of existing research. ICES Cooperative Research Reports, Vol. 354. 64 pp. <u>https://doi.org/10.17895/ices.pub.19248542</u>.

Drabble, R. (2012) Projected entrainment of fish resulting from aggregate dredging. Marine Pollution Bulletin. Volume 64, Issue 2, February 2012, Pages 373-381.

Ellwood, H. (2014). Creating a EUNIS level 3 seabed habitat map integrating data originating from maps from field surveys and the EUSeaMap model. JNCC

EMODnet, (2010). MESH Confidence Assessment. [Online] Available at: <u>http://www.emodnet-seabedhabitats.eu/default.aspx?page=1635</u> (Accessed: 01/12/2021).

EMODnet, (2021a). Seabed Habitats. [Online] Available at: <u>https://emodnet.ec.europa.eu/en/seabed-habitats</u> (Accessed: 01/12/2021).

EMODnet, (2021b). Human Activities. [Online] Available at: <u>https://www.emodnet-humanactivities.eu/</u> Accessed: 01/12/2021).

European Environment Agency, (EEA), (2017). EEA marine assessment grid, Jan. 2017. European EnvironmentAgencyGeospatialDataCatalogue.[Online]Availableat:https://sdi.eea.europa.eu/catalogue/srv/eng/catalog.search#/metadata/84d1f816-1913-45b1-94b7-a5721a18296c(Accessed 08/11/2021).

European Environment Agency, (EEA), (2021). EUNIS Habitat Classification. [Online] Available at: <u>https://www.eea.europa.eu/data-and-maps/data/eunis-habitat-classification-1</u>. (Accessed: 08/11/2021).

Grolemund, G. & Wickham, H., (2011). Dates and Times Made Easy with lubridate. Journal of Statistical Software, 40(3), 1-25. Available at: <u>https://www.jstatsoft.org/v40/i03/</u>.

Holling C.S. (1973). Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics*, 4(1), 1-23.

Holt, T.J., Jones, D.R., Hawkins, S.J. & Hartnoll, R.G. (1995). The sensitivity of marine communities to maninduced change - a scoping report. Countryside Council for Wales, Bangor, CCW Contract Science Report, no. 65.

ICES (2015). Report of the Working Group on Spatial Fisheries Data (WGSFD). http://www.ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Report/SSGEPI/2015/01%20W GSFD%20-%20Report%20of%20the%20Working%20Group%20on%20Spatial%20Fisheries%20Data.pdf

ICES (2016). Effects of extraction of marine sediments on the marine environment 2005–2011. ICES Cooperative Research Report No. 330. 206 pp ISBN 978-87-7482-179-3 ISSN 1017-6195 Available at: https://doi.org/10.17895/ices.pub.5498

ICES (2019a). Workshop to evaluate and test operational assessment of human activities causing physical disturbance and loss to seabed habitats (MSFD D6 C1, C2 and C4) (WKBEDPRES2). ICES Scientific Reports. 1:69. 87 pp. http://doi.org/10.17895/ices.pub.5611

ICES (2019b). Working Group on the Effects of Extraction of Marine Sediments on the Marine Ecosystem (WGEXT). ICES Scientific Reports. 1:87. 133 pp. http://doi.org/10.17895/ices.pub.5733

JNCC (2011). *Review of methods for mapping anthropogenic pressures in UK waters in support of the Marine Biodiversity Monitoring R&D Programme*. Briefing paper to UKMMAS evidence groups. Presented 06/10/2011.

Kenny, A.J., Rees, H.L. (1994). The effects of marine gravel extraction on the macrobenthos: Early postdredging recolonization. *Marine Pollution Bulletin*. Volume 28, Issue 7, July 1994, Pages 442-447.

Last, E.K., Matear, L., & Robson, L.M. (2020). Developing a method for broadscale & feature-level sensitivity assessments: the MarESA aggregation. JNCC Report No. 662, JNCC, Peterborough, ISSN 0963-8091.

Last, K. S., Hendrick, V. J., Beveridge, C. M., & Davies, A. J. (2011). Measuring the effects of suspended particulate matter and smothering on the behaviour, growth and survival of key species found in areas associated with aggregate dredging. pp. 70

Manca, E. & Lillis H. (2022). 2019 Update to UKSeaMap – a broad-scale seabed habitat map for the UK. *In prep.* 

MST (2021). Ministry of Environment of Denmark, extraction sites. [Online] Available at: <u>https://miljoegis.mim.dk/cbkort?profile=miljoegis-raastofferhavet</u> (Accessed 01/12/2021)

Moss, D. (2008). EUNIS Habitat classification - a guide for users. *European Topic Centre on Biological Diversity*. [Online] Available at: <u>https://www.eea.europa.eu/data-and-maps/data/eunis-habitat-classification</u> (Accessed 03/02/2022)

Newell, R. C., Seiderer, L. J., & Hitchcock, D. R. (1998). The impact of dredging works on coastal waters: A review of the sensitivity to disturbance and subsequent recovery of biological resources on the seabed. *Oceanography and Marine Biology.* 36, 127-78.

Newell, R. C., & Woodcock, T. A. (2013). Aggregate dredging and the marine environment: an overview of recent research and current industry practice. *The Crown Estate*. 165pp ISBN: 978-1-906410-41-4.

NIBS (2021). Niedersächsischen Bodeninformationssystems Thematic maps, Mining production licences. [Online] Available at: <u>https://nibis.lbeg.de/cardomap3/?lang=en</u> (Accessed 01/12/2021)

Noordzeeloket (2022). Surface Mineral Extraction. [Online] Available at: <u>https://www.noordzeeloket.nl/en/functions-and-use/artikel-baseline/</u> (Accessed 01/02/2022)

OneBenthic database. (2020). Available from https://openscience.cefas.co.uk/OneBenthicExtraction/. Accessed: 01/09/2022.

OSPAR Commission (2009). Summary assessment of sand and gravel extraction in the OSPAR maritime area. Publication number 434/2009. <u>https://www.ospar.org/documents?v=7149</u>

OSPAR Commission (2011). Pressure list and descriptions. Paper to ICG-COBAM 11/8/1 Add.1-E (amended version 25th March 2011) presented by ICG-Cumulative Effects. OSPAR Commission, London.

OSPAR Commission (2014). OSPAR Joint Assessment and Monitoring Programme (JAMP) 2014-2023. [Online] Available at: http://www.ospar.org/documents?d=32988. (Accessed 10/11/2021)

OSPAR Commission (2017a). OSPAR Intermediate Assessment 2017. OSPAR Commission. London.

OSPAR Commission (2017b). OSPAR Coordinated Environmental Monitoring Programme (CEMP) Guidelines. Common Indicator: BH3 Extent of Physical damage to predominant and special habitats (https://www.ospar.org/documents?v=37641).

OSPAR Commission (2019). QSR 2023 Guidance Document. OSPAR Agreement 2019-02. https://www.ospar.org/documents?v=40951

OSPAR Commission, (2021). Feeder Report 2021 – Extraction of non-living Resources. Version 1.0.0. [Online]. Available at: <u>https://oap.ospar.org/en/ospar-assessments/quality-status-reports/qsr-2023/other-assessments/extraction-non-living-resources/</u> (Accessed 28/04/2022)

Pebesma, E. (2018). Simple Features for R: Standardized Support for Spatial Vector Data. *The R Journal* 10 (1), 439-446.

Python Software Foundation, (2020). Python Language Reference, version 3.7.11. Available at <u>http://www.python.org</u>

R Core Team (2019). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL <u>https://www.R-project.org//.</u>

R Core Team (2020). R: A language and environment for statistical computing. *R Foundation for Statistical Computing, Vienna, Austria*. Available at <u>https://www.R-project.org/</u>.

R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available at <u>https://www.R-project.org/</u>.

Robinson, L.A., Rogers S. & Frid, C.L.J., (2008). A marine assessment and monitoring framework for application by UKMMAS and OSPAR - Assessment of Pressures and Impacts. Phase II: Application for regional assessments. JNCC Contract No: C-08-0007-0027. UKMMAS, 2010. Charting Progress 2.

Robson, L.M., Fincham, J., Peckett, F.J., Frost, N., Jackson, C., Carter, A.J., & Matear, L. (2018). UK Marine Pressures-Activities Database "PAD": Methods Report. JNCC Report No. 624, JNCC, Peterborough, ISSN 0963-8091.

Schroeder, A., Gutow, L. & M. Gusky (2008). FishPact. Auswirkungen von Grundschleppnetzfischereien sowie von Sand- und Kiesabbauvorhaben auf die Meeresbodenstruktur und das Benthos in den Schutzgebieten der deutschen AWZ der Nordsee (MAR 36032/15). Report for the Bundesamt für Naturschutz.

The Crown Estate, (2021). Introduction. *Electronic Monitoring System Annual Report 2020*. [Online] Available at: <u>https://www.thecrownestate.co.uk/media/3995/2021-ems-report.pdf</u> (Accessed April 2022)

Tillin, H. M., Houghton, J. Saunders, E., Drabble, R., & Hull, S. C. (2011). Direct and Indirect Impacts ofAggregate Dredging. Science Monograph Series No. 1. Marine ASLF. 41pp.ISBN:9780907545439.

Tillin, H.M., Hull, S.C. & Tyler-Walters, H (2010). Development of a Sensitivity Matrix (pressures-MCZ/MPAfeatures).DefraContractNo.MB0102Task3A,ReportNo.22.http://jncc.defra.gov.uk/pdf/MB0102SensitivityAssessment%5B1%5D.pdf

Tillin, H. & Tyler-Walters, H. (2014a). Assessing the sensitivity of subtidal sedimentary habitats to pressures associated with marine activities. Phase 1 Report: Rationale and proposed ecological groupings for Level 5 biotopes against which sensitivity assessments would be best undertaken. JNCC Report No. 512A, 68 pp. Available from http://jncc.defra.gov.uk/page-6790

Tillin, H. & Tyler-Walters, H. (2014b). Assessing the sensitivity of subtidal sedimentary habitats to pressures associated with marine activities. Phase 2 Report – Literature review and sensitivity assessments for ecological groups for circalittoral and offshore Level 5 biotopes. JNCC Report No. 512B, 260 pp. Available from: http://jncc.defra.gov.uk/PDF/Report 512-B\_phase2\_web.pdf

Tillin, H.M. & Tyler-Walters, H. (2015). Finalised list of definitions of pressures and benchmarks for sensitivity assessment. 7-9.

Tyler-Walters, H., Tillin, H.M., d'Avack, E.A.S., Perry, F. & Stamp, T. (2018). Marine Evidence\_based Sensitivity Assessment (MarESA) – A Guide. Plymouth: Marine Biological Association. Marine Management Organisation, (2019). Dredging Guidance: Dredging by Type. *Dredging – GOV.UK.* [Online] Available at: <u>https://www.gov.uk/guidance/dredging#dredging-by-type</u> (Accessed April 2022).

Van Loon, W.M.G.M., Boon, A.R., Gittenberger, A., Walvoort, D.J.J., Lavaleye, M., Duineveld, G.C.A., & Verschoor, A.J. (2015). Application of the Benthic Ecosystem Quality Index 2 to benthos in Dutch transitional and coastal waters, Journal of Sea Research, Volume 103, 1-13.

Van Loon, W.M.G.M., Walvoort, D.J., Van Hoey, G., Vina-Herbon, C., Blandon, A., Pesch, R., Schmitt, P., Scholle, J., Heyer, K., Lavaleye, M. & Phillips, G., (2018). A regional benthic fauna assessment method for the Southern North Sea using Margalef diversity and reference value modelling. Ecological Indicators, 89, 667-679.

Vlasblom, W.J. (2005). Designing Dredging Equipment: Chapter 2 Trailing suction hopper dredger. Pp 13.

Vasquez, M., Allen, H., Manca, E., Castle, L., Lillis, H., Agnesi, S., Al Hamdani, Z., Annunziatellis, A., Askew, N., Bekkby, T., Bentes, L., Doncheva, V., Drakopoulou, V., Duncan, G., Gonçalves, J., Inghilesi, R., Laamanen, L., Loukaidi, V., Martin, S., McGrath, F., Mo, G., Monteiro, P., Muresan, M., Nikilova, C., O'Keeffe, E., Pesch, R.,

Pinder, J., Populus, J., Ridgeway, A., Sakellariou, D., Teaca, A., Tempera, F., Todorova, V., Tunesi, L. & Virtanen, E., (2021). EUSeaMap 2021, A European broad-scale seabed habitat map, Technical Report. https://doi.org/10.13155/83528.

Wickham, H., Averick, M., Bryan, J., Chang, W., McGowan, L.D.A., François, R., Grolemund, G., Hayes, A., Henry, L., Hester, J., Kuhn, M., Pedersen, T., Miller, E., Bache, S., Müller, K., Ooms, J., Robinson, D., Seidel, D., Spinu, V., Takahashi, K., Vaughan, D., Wilke, C., Woo, K. and Yutani, H., (2019). Welcome to the tidyverse. *Journal of Open-Source Software*, 4(43), 1686.

Zacharias, M. A. & Gregr, E. J. (2005). Sensitivity and Vulnerability in Marine Environments: an Approach to Identifying Vulnerable Marine Areas. *Conservation Biology*. 19, 86-97.

# Annex 1: Development of a composite habitat map for OSPAR regions

#### Introduction

The specification for a habitat map for the assessment included the following conditions:

- To contain information on the relevant EUNIS habitat / biotope type at any level between EUNIS Levels 2 and 6;
- To refer data on biotopes to Level 3 of the EUNIS habitat classification system;
- To use the broad-scale modelled map, EUSeaMap when higher resolution maps from surveys were not available;
- To use the best available evidence on habitat data;
- To cover the greatest possible area of the OSPAR Maritime Area;
- To contain no overlaps; and
- To enable classification to Broad Benthic Habitat Types (BHT) under MSFD where possible.

The datasets listed below were combined together following the method in a way that ensured that only one data source was present at any one location.

#### Method

The OSPAR-scale habitat map integrated component habitat maps from both *in-situ* survey datasets and modelled MSFD Benthic Broad Habitat Types or EUNIS habitat data (in the absence of direct sample data). Habitats were mapped to the highest resolution of detail available, ranging from EUNIS Level 2 (physical habitats) to Level 6 (biological communities) via the following data sources and processes:

- 1. EUNIS habitat maps derived from surveys within the OSPAR Maritime Area extracted from EMODnet Seabed Habitats Data Portal.
- 2. Remaining gaps filled by EUSeaMap 2021 (Broad-scale predictive habitat maps) comprising:
  - EUSeaMap 2021 (Vasquez *et al.*, 2021) which covered all European sea basins where the EMODnet Geology seabed substrate map is available.
  - UKSeaMap 2018 (Manca & Lillis, 2020, in-prep.) a version of EUSeaMap that incorporated greater spatial resolution data available in United Kingdom waters, as revised by the Joint Nature Conservation Committee (JNCC). UKSeaMap 2018 was incorporated to ensure the highest resolution of data was used where available.

Please note that due errors in translation tables (at the time of assessment) between EUNIS 2007 and later versions (e.g., EUNIS 2019), newer versions of the EUNIS classification have not been used in this assessment.

EUSeaMap is updated every 2-3 years, developed using a suite of EMODnet products, including EMODnet Bathymetry, EMODnet Geology and Copernicus marine services via the Copernicus Marine Environment Monitoring Service (CMEMS) (Vasquez, *et al.*, 2021). Additional physical data used for

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the calculation of the models include data on light attenuation, light at the seabed and kinetic, current and wave energy datasets. For further detail on associated data products, please see EMODnet (2021).

EUSeaMap data were combined with *in-situ* survey datasets across the OSPAR Maritime Area through two confidence-scoring mechanisms to ensure the best available data were mapped. Primarily, data were analyzed for MESH (Mapping European Seabed Habitats) confidence, which assessed the quality of the processes used to create the map (e.g., maps derived from remote sensing and ground-truthing to inform habitat classification were prioritised over modelled data) (Castle *et al.*, 2021). Subsequently, maps were reanalysed using a three-step confidence-scoring mechanism to produce a qualitative score, indicative of the likelihood of habitats being mapped correctly within a study area (please see Ellwood, (2014) for full detail of the three-step confidence assessment):

- 1. Remote sensing coverage
- 2. Amount of sampling
- 3. Distinctness of class boundaries

To ensure that the OSPAR-scale composite habitat map met the above conditions, the following quality controls were applied to all source data prior to use:

- Restricted and public data were identified; only publicly available data were considered in analyses.
- Mosaic habitats were formatted using the same schema as the previous combined map.

All data included were also quality checked using a five-stage stepwise method to resolve GIS errors and overlapping habitat polygons to ensure that the most accurate polygon was represented in final map outputs. An overview of the five stages is represented below:

- 1. If one layer contained all intertidal habitats and another layer contained all subtidal habitats, the layer containing all intertidal habitats was used. A prioritisation of layers containing intertidal habitats was undertaken, as intertidal maps were generally produced with better detail and resolution than subtidal data and therefore, had better accuracy. Where both layers contained all intertidal or all subtidal habitats, or either layer contained a mixture of intertidal and subtidal habitats, stage 2 was implemented.
- 2. The layer with the highest 3-step confidence score was used, where the 3-step confidence score was the same, stage 3 was implemented.
- 3. The layer derived from survey data was prioritised over modelled data derived from EUSeaMap; where both layers were based on survey data, stage 4 was implemented.
- 4. The layer with the highest MESH confidence score was used; where both layers shared the same MESH confidence score, stage 5 was implemented.
- 5. Expert judgement on the most likely layer to indicate EUNIS Level 3 habitat was applied, and that layer was used.

This process was repeated until all overlapping polygons had been resolved within the layer. Once overlapping polygons had been resolved to represent the habitat most likely present in the area, a 'Repair Geometry' tool was used to resolve any geometry errors in the OSPAR-scale composite habitat map. Please see Castle *et al.* (2021) for further information on the methodology used to create the composite habitat map product. Final product can be found in Figure A1.1



Figure A1.1. OSPAR Composite habitat map integrating maps from surveys and broad-scale models.

#### Translations to MSFD Broad Benthic Habitat Types

To maximise usability of assessment results for Contracting Parties that report against Article 8 of the MSFD, disturbance outputs based on EUNIS 2007 habitat codes were assigned to the appropriate BBHT in the MSFD classification system. A translation table was created by habitat classification experts at JNCC and EMODnet to facilitate correlation between EUNIS habitat and BHTs, supplied as an addition Annex csv. document (Table A1.1). In some instances, translations required combinations of EUNIS code, biological zone and / or substrate information to correctly assign BHT where EUNIS habitats contained or partially overlapped with multiple BHTs. Biological zone and substrate information was obtained from a spatial intersect of the disturbance layer with EUSeaMap 2021 (Vasquez *et al.*, 2021) using ArcGIS v.10.1. Once disturbance layers were intersected with EUSeaMap 2021, translations were carried out in R (versions ranging from 3.6.1 - 4.1.2; R core team 2019-2021) using the tidyverse (Wickham et al., 2019), sf (Pebesma, E., 2018) packages. Habitat codes, biological zone, and substrate type information were joined in a stepwise process to provide the corresponding BHT. EUNIS habitat features that couldn't be assigned MSFD translations (e.g., lacking substrate information) were designated "No EUNIS to MSFD BBHT translation". Please see supplementary R script for full detail on the methods used.

Table A1.1: Example of EUNIS 2007 to MSFD BBHT translation table supplied as a supplementary document.

EUNIS07code	EUNIS07_name	Biological_zone	Substrate_type	Relationship_name	MSFD
A5.151	[Glycera lapidum], [Thyasira] spp. and [Amythasides macroglossus] in offshore gravelly sand			Is contained within	Offshore circalittoral coarse sediment
A5.152	[Hesionura elongata] and [Protodorvillea kefersteini] in offshore coarse sand			Is contained within	Offshore circalittoral coarse sediment
A5.2	Sublittoral sand	Infralittoral		Is contained within	Infralittoral sand
A5.2	Sublittoral sand	Circalittoral		Is contained within	Circalittoral sand
A5.2	Sublittoral sand	Offshore circalittora	I	Is the same as	Offshore circalittoral sand

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# Annex 2. Sensitivity Assessment of Species and Habitats

#### Introduction

Sensitivity can be defined as the ability of a species or habitat to withstand changes to the surrounding environmental conditions (Holt et al., 1995; Tyler-Walters, 2010; Zacharias and Gregor, 2005). This can be understood as a function of a species or habitat's ability to tolerate or resist change (resistance) and its ability to recover from disturbance or stress (resilience) (Tillin et al., 2010; BioConsult, 2013; Tillin and Tyler-Walters, 2014a & 2014b). Both elements are essential for a sensitivity analysis, in particular when the data are going to be evaluated to assess not just impact at a particular location at a point in time, but also the temporal effects of pressures over time. A species or habitat that is considered sensitive is therefore one that has both low levels of resistance and resilience, whereas a species or habitat that is considered to be not sensitive or has low sensitivity is one with both high levels of resistance and resilience.

#### Sensitivity assessments of an ecosystem

The sensitivity of an ecosystem can be assessed in a number of different ways. More traditional methods have assessed the sensitivity of a broad scale habitats on a categorical scale of none to high based on expert judgement (e.g., Tillin et al., 2010), such as the information used in the UK sensitivity assessment carried out for MCZ designation. However, more recent methods assess the sensitivity of key structural, functional, and characterising species of benthic habitats in relation to a defined intensity of a given pressure. In MB0102, species that characterised sublittoral rock and sediment habitats were assessed for their sensitivity to pressures in groups of taxa with similar biological traits. The resistance and resilience of characteristic species were assessed in response to defined pressures via literature review and expert judgement. Please see Tillin and Walters (2014b), Maher and Alexander (2016) for details of habitat characterising species, trait-based groupings, sensitivity assessments and assessment confidence scores.

Since the OSPAR Intermediate Assessment, 2017 (IA 2017) updated habitat sensitivity information, assessed following the Marine Evidence-based Sensitivity Assessment (MarESA) methodology (Tyler-Walters et al., 2018) has been made available. The MarESA

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method is a scientific approach to assessing habitat (including habitat characterising species) sensitivity to a range of pressures, based on those defined by the OSPAR Intercessional Correspondence Group on Cumulative Effects (OSPAR 2014; Tyler-Walters et al., 2018). All sensitivity assessments undergo quality assurance checks by the MarLIN Editor and, wherever possible, are peer reviewed by one or more independent expert(s), nominated for their expertise relevant to the assessed features (Tyler-Walters, et al., 2018). When developing BH3 sensitivity layers, MarESA was prioritised over MB0102 sensitivity due to improved data quality and accuracy. Additional sources of habitat and species sensitivity assessments were investigated for incorporation into the BH3 method, including Sentinels of Seabed (SoS) indicator (Serrano et al., 2022) and Condition of benthic habitat communities (OSPAR, 2018).

MarESA sensitivity assessments used in this assessment were undertaken at a biotope scale using the following steps (see Tyler-Walters *et al.*, 2018 for full method):

1. Establish and define the key components of the assessed feature, considered relevant to the assessment (e.g., traits such as life history and the ecology of the key and characterizing species) (Table A2.1).

Category	Description					
Key The species provides a distinct habitat that supports an asso						
structural	community. Loss/degradation of this species population would result in					
species	loss/degradation of the associated community.					
Кеу	Species that maintain community structure and function through					
functional	interactions with other members of that community (for example through					
species	predation, or grazing). Loss/degradation of this species population would					
	result in rapid, cascading changes in the community.					
Important	Species characteristic of the biotope (dominant, and frequent) and					
characteristic	important for the classification of the habitat. Loss/degradation of these					
<b>species</b> species populations may result in changes in habitat classification.						

Table A2.1 Definitions of key components of feature used in sensitivity assessment, adapted from Tyler-Walters et al., (2018).

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# 2. Assess the feature's resistance and resilience to a defined intensity of a given pressure (pressure benchmark, Table A2.2).

Table A2.2: Pressures from OSPAR ICG-C relevant to assessments of surface, subsurface and extraction pressure (OSPAR, 2011).

OSPAR ICG-C	Assessment	Definition				
Pressure	benchmark					
Abrasion/dist urbance at the surface of the substratum	Benthic species /habitats: damage to surface features (e.g., species and physical structures within the habitat)	Physical disturbance or abrasion at the surface of the substratum in sedimentary or rocky habitats. The effects are relevant to epiflora and epifauna living on the surface of the substratum. In intertidal and sublittoral fringe habitats, surface abrasion is likely to result from recreational access and trampling (inc. climbing) by human or livestock, vehicular access, moorings (ropes, chains), activities that increase scour and grounding of vessels (deliberate or accidental). In the sublittoral, surface abrasion is likely to result from pots or creels, cables and chains associated with fixed gears and moorings, anchoring of recreational vessels, objects placed on the seabed such as the legs of jack-up barges, and harvesting of seaweeds (e.g., kelps) or other intertidal species (trampling) or of epifaunal species (e.g., oysters). In sublittoral habitats, passing bottom gear (e.g., rock hopper gear) may also cause surface abrasion to epifaunal and epifloral communities, including epifaunal biogenic reef communities. Activities associated with surface abrasion can cover relatively large spatial areas e.g., bottom trawls or bio-prospecting or be relatively localized activities e.g. seaweed harvesting, recreation, notting, and aquaculture				
Penetration and/or disturbance of the substratum below the surface	Benthic species /habitats: damage to sub- surface features (e.g., species and physical structures within the habitat)	Physical disturbance of sediments where there is limited or no loss of substratum from the system. This pressure is associated with activities such as anchoring, taking of sediment/geological cores, cone penetration tests, cable burial (ploughing or jetting), propeller wash from vessels, certain fishing activities, e.g., scallop dredging, beam trawling. Agitation dredging, where sediments are deliberately disturbed by and by gravity & hydraulic dredging where sediments are deliberately disturbed and moved by currents could also be associated with this pressure type. Compression of sediments, e.g., from the legs of a jack-up barge could also fit into this pressure type. Abrasion relates to the damage of the seabed surface layers (typically up to 50 cm depth). Activities associated with abrasion can cover relatively large spatial areas and include fishing with towed demersal trawls (fish & shellfish); bio-prospecting such as harvesting of biogenic features such as maerl beds where, after extraction, conditions for recolonization remain suitable or relatively localised activities including seaweed harvesting, recreation, potting, aquaculture. Change from gravel to silt substrata would adversely affect herring spawning grounds. Loss, removal or modification of the substratum is not included within this pressure (see the physical loss pressure theme). Penetration and damage to the soft rock substrata are considered, however, penetration into hard bedrock is deemed unlikely.				
Habitat	Extraction of	Unlike the "physical change" pressure type where there is a permanent change in				
structure	substratum to 30	sea bed type (e.g. sand to gravel, sediment to a hard artificial substratum) the				
changes -	cm (where	"habitat structure change" pressure type relates to temporary and/or reversible				
removal of	substratum	change, e.g. from marine mineral extraction where a proportion of seabed sands				
substratum	includes	or gravels are removed but a residual layer of seabed is similar to the pre-dredge				
(extraction)	sediments and	structure and as such biological communities could re-colonize; navigation				

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OSPAR ICG-C Assessment		Definition			
Pressure benchmark					
	soft rocks but	dredging to maintain channels where the silts or sands removed are replaced by			
	excludes hard	non-anthropogenic mechanisms so the sediment typology is not changed.			
	bedrock)				

To inform habitat sensitivity, the resistance and resilience of a given receptor were assessed, based on standardised criteria, using the best available evidence in the literature at the time of assessment; scales of assessment for resistance and resilience are given in Table A2. 3 and Table A2.4, respectively.

Table A2. 3: Criteria used to assess resistance using the MarESA method, adapted from Tyler-Walters et al., (2018)

Resistance	Description		
None	Key functional, structural, characterizing species severely decline and/or		
	physicochemical parameters are also affected e.g. removal of habitats causing		
	a change in habitats type. A severe decline/reduction relates to the loss of		
	75% of the extent, density or abundance of the selected species or habitat		
	component e.g. loss of 75% substratum (where this can be sensibly applied).		
Low	Significant mortality of key and characterizing species with some effects on		
	the physicochemical character of habitat. A significant decline/reduction		
	relates to the loss of 25-75% of the extent, density, or abundance of the		
	selected species or habitat component e.g. loss of 25-75% of the substratum.		
Medium Some mortality of species (can be significant where these are not			
	structural/functional and characterizing species) without change to habitats		
	relates to the loss <25% of the species or habitat component.		
High	No significant effects on the physicochemical character of habitat and no		
	effect on population viability of key/characterizing species but may affect		
	feeding, respiration and reproduction rates.		

Table A2.4 Criteria used to assess resilience using the MarESA method, adapted from Tyler-Walters et al., (2018)

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Resilience	Description
Very Low	Negligible or prolonged recovery possible; at least 25 years to recover
	structure and function
Low	Full recovery within 10-25 years
Medium	Full recovery within 2-10 years
High	Full recovery within 2 years

# 3. Combine resistance and resilience to derive a sensitivity score to a defined intensity of a given pressure (pressure benchmark, Table A2.2).

Resistance and resilience scores to a given pressure are combined to produce a sensitivity score for a habitat or species. A matrix is used to represent the combination of resistance and resilience into a single sensitivity score ranging from 1 to 5 (with 5 being the most sensitive; Table A2.5) for the associated pressure.

Sensitivity		Resilience						
		very low (>25 yr.)	/ low (>10-25 yr.)	medium (>2-10 yr.)	high (1-2 yr.)	very high (<1 yr.)		
Resistance none		5	4	4	3	2		
	low	4	4	3	3	2		
	medium	4	3	3	2	1		
	high	3	3	2	2	1		

Table A2.5 Sensitivity matrix combing resistance and resilience scores to produce a sensitivity score ranging from 1 to 5, where 5 is the most sensitive

MarESA assessments are available for a diversity of biotopes, ranging from Levels 6 to 4 of the EUNIS 2007 classification, drawing from the best-available evidence, complete with detailed evaluations and audit trails of the information used to assess sensitivity (Tyler-

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Walters, 2018; Last et al. 2020). Although MarESA assessments enable detailed biotoperesolution sensitivity and disturbance assessments, understanding of broadscale habitat sensitivity is also required for application to the BH3 indicator. Therefore, automated methods based on the JNCC MarESA Aggregation approach were developed in Python 3.6 (Python Software Foundation, 2020), to aggregate from biotope-resolution resistance and resilience data to all higher hierarchical tiers of the EUNIS 2007 classification (Last et al., 2020). The MarESA aggregation enables end users to understand the component child biotope assessments throughout the EUNIS 2007 classification (Last et al., 2020). Aggregation of resistance and resilience values independently across tiers of the EUNIS hierarchy enabled child biotope resistance and resilience values to be assigned to parent biotopes in line with the precautionary principle, returning the lowest respective resistance and resilience values to assessed pressures. An example of the aggregated resistance score for child biotopes of EUNIS 2007 A5.4 habitat is given in Table A2.6. Aggregated resistance and resilience values were then converted to sensitivity scores using the aforementioned sensitivity matrix (Table A2.5) to obtain the most precautionary sensitivity value derived from child biotopes; please see supplementary Python scripts for full detail on the methods used. However, when aggregating biotope sensitivities at Level 4 or lower, any assessment that had been made at Level 5 or 6 were omitted if the biotope had been assessed at Level 4; as Level 4 sensitivity assessments were conducted specifically to account for known child biotope sensitivities (EUNIS 2007 Level 5 and 6). Overall, the aggregation of MarESA assessments enabled disturbance to be calculated at the greatest level of resolution available in the OSPAR-scale composite habitat map and summarised at broadscale habitat when further detail was not available.

Table A2.6: Example structure of aggregated resistance values across EUNIS 2007 classification (A5.4, EUNIS 2007 Level 3 to biotope-scale, EUNIS 2007 Level 6) for surface abrasion pressure, using a precautionary approach. Note, resistance is one component of sensitivity, calculated using a combination of resistance and resilience.

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EUNIS Level	Level 3 Resistance		Level 4 Resistance	EUNIS	Level 5	EUNIS	Level 6
3	Range	EUNIS Level 4	Range	Level 5	<b>Resistance Range</b>	Level 6	Resistance Range
		A5.41 (Unknown)	Unknown	A5.411	Unknown		
				A5.412	Unknown		
		A5.42 (Low)	Low	A5.421	Low		
				A5.422	Low		
				A5.431	Low	No	child biotopes
			Medium, Low, None	A5.432	Low		
		A5.43 (None)		A5.433	Medium		
				A5.434	None		
				A5.435	Low		
		A5.44 (Low)	Medium, Low	A5.441	Medium	A5.4411	Medium
A5.4 (None)	Medium, Low, None			A5.442	Low		
				A5.443	Medium		
				A5.444	Low		
				A5.445	Low		
				A5.446	Unknown		
		A5.45 (Medium)	Medium	A5.451	Medium	No	child biotopes
		A5.46 (Unknown)	Unknown	A5.461	Unknown		
				A5.462	Unknown		
				A5.463	Unknown		
		A5.47 (Unknown)	Unknown	A5.471	Unknown		
				A5.472	Unknown		

In addition to aggregated habitat sensitivity information, BH3 includes the sensitivity of *insitu* sampled species records. As this indicator is applied at an OSPAR Regional scale, it is acknowledged that species may react differently in different Regions, due to variations in environmental factors, the characteristics of local populations and their roles in the function of benthic assemblages. Therefore, it is important to ensure that relevant sensitivity information at a regional level is used and where possible, sensitivity should be based on the consistent parameters; resistance and resilience in relation to a specific pressure and that the same scales for resistance and resilience are used / combined in the same matrix.

Species-specific resistance and resilience scores from MarESA and MB0102 were combined to maximise data coverage, increasing the total number of species with associated sensitivity assessments (Table A2.7). Species-specific resistance and resilience scores for the associated pressures were combined into a single sensitivity score using the same process described for habitat sensitivity (Table A2.5). In instances where multiple sensitivity scores
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were available for the same species, scores with the highest confidence were assigned, if confidence assessments were equal, then the most precautionary values were used.

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Table A2.7: BH3 species sensitivity values derived from Tyler-Walters et al., 2018 (MarESA), Tillin & Tyler-Walters 2014a & 2014b (Sediment), and Maher & Alexander 2016; Maher et al., 2016 (Sublittoral rock).

Species	Abrasion/disturbancePenetration and/orAbrasion/disturbancedisturbance of theHabitateof the substrate onsubstrate belowchangesthe surface of thethe surface of theof subsseabedseabed, including(extra abrasion		Habitat structure changes - removal of substratum (extraction)	Sensitivity assessment source	
Abra alba	2	2	3	Sediment	
Abra nitida	3	3	4	Sediment	
Abra prismatica	3	3	4	Sediment	
Alcyonium digitatum	3	3	4	Sediment; Sublittoral rock	
Alkmaria romijni	3	3	4	MarESA	
Ampharete falcata	3	3	4	Sediment	
Amphianthus dohrnii	3	Not Assessed	Not Assessed	MarESA	

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Species	Abrasion/disturbance of the substrate on the surface of the seabed	Penetration and/or disturbance of the substrate below the surface of the seabed, including abrasion	Habitat structure changes - removal of substratum (extraction)	Sensitivity assessment source	
Amphiura filiformis	3	3	4	Sediment	
Arctica islandica	4	4	5	MarESA	
Ascidiella aspersa	3	3	3	Sediment	
Asterias rubens	2	3	4	Sediment; Sublittoral rock	
Astropecten irregularis	3	3	4	Sediment	
Atrina fragilis	3	5	5	MarESA	
Axinella dissimilis	3	Not Assessed	Not Assessed	Sublittoral rock	
Balanus crenatus	3	3	3	Sediment	
Bathyporeia elegans	2	2	3	Sediment	
Branchiostoma lanceolatum	3	3	3	Sediment	
Brissopsis lyrifera	2	3	4	Sediment	

		_			
Species	Abrasion/disturbance of the substrate on the surface of the seabed abrasion		Habitat structure changes - removal of substratum (extraction)	Sensitivity assessment source	
Caecum armoricum	3	5	5	MarESA	
Calocaris macandreae	3	4	4	Sediment	
Calvadosia campanulata	3	5	5	MarESA	
Calvadosia cruxmelitensis	nelitensis 3 4		4	MarESA	
Cancer pagurus	2	No Information	Not Assessed	Sublittoral rock	
Cerianthus lloydii	3	3	3	Sediment	
Chaetozone zetlandica	3	3	4	Sediment	
Cladophora rupestris	2	Not Assessed	Not Assessed	Sublittoral rock	
Clavelina lepadiformis	3	Not Assessed Not Assessed		Sublittoral rock	
Cliona celata	2	Not Assessed	Not Assessed	Sublittoral rock	
Dipolydora caulleryi	2	3	3	Sediment	

		_			
Species	Abrasion/disturbance of the substrate on the surface of the seabed	Penetration and/or disturbance of the substrate below the surface of the seabed, including abrasion	Habitat structure changes - removal of substratum (extraction)	Sensitivity assessment source	
Dysidea fragilis	3	Not Assessed	Not Assessed	Sublittoral rock	
Echinocardium cordatum	2	3	4	Sediment	
Echinocyamus pusillus	2	3	4	Sediment	
Echinus esculentus	3	3	3	Sediment; Sublittoral rock	
Electra pilosa	3	Not Assessed	Not Assessed	Sublittoral rock	
Eudorellopsis deformis	2	3	3	Sediment	
Eunicella verrucosa	3	Not Assessed	Not Assessed	MarESA	
Flustra foliacea	2	3	4	Sediment; Sublittoral rock	
Funiculina quadrangularis	4	4	4	Sediment	
Gammarus insensibilis	3	Not Assessed	5	MarESA	

Species	Abrasion/disturbance of the substrate on the surface of the seabed	Penetration and/or disturbance of the substrate below the surface of the seabed, including abrasion	Habitat structure changes - removal of substratum (extraction)	Sensitivity assessment source	
Glycera lapidum	2	3	4	Sediment	
Haliclystus auricula	3	4	5	MarESA	
Halidrys siliquosa	2	Not Assessed	Not Assessed	Sublittoral rock	
Hippocampus hippocampus	3	3	2	MarESA	
Iphinoe trispinosa	2	3	3	Sediment	
Laminaria hyperborea	2	Not Assessed	Not Assessed	Sublittoral rock	
Lanice conchilega	2	2	4	Sediment; Sublittoral rock	
Lithothamnion corallioides	5	5	5	MarESA	
Maxmuelleria lankesteri	3	3	3	Sediment	
Modiolus modiolus	4	4	4	Sediment	
Mytilus edulis	2	No Information	Not Assessed	Sublittoral rock	

Species	Abrasion/disturbancePenetration and/or disturbance of the substrate belowHa the substrate belowof the substrate on the surface of the seabedsubstrate below the surface of the seabed, including abrasionHa		Habitat structure changes - removal of substratum (extraction)	Sensitivity assessment source
Nematostella vectensis	2	2 2 5		MarESA
Nemertesia ramosa	3	3	3	Sediment
Neopentadactyla mixta	2	3	5	Sediment
Nephrops norvegicus	3	3	4	Sediment
Nephtys hombergii	2	2	3	Sediment
Nucella lapillus	2	No Information	Not Assessed	Sublittoral rock
Obelia longissima	3	3	3	Sediment
Ophiocomina nigra	3	3	4	Sediment
Ophiothrix fragilis	3	3	4	Sediment
Ophiura albida	3	3	4	Sediment
Ostrea edulis	4	4	5	MarESA

Species	Abrasion/disturbance of the substrate on the surface of the seabedPenetration and/or disturbance of the substrate below the surface of the seabed, including abrasionHabitat stru changes - reg of substrate of substrate		Habitat structure changes - removal of substratum (extraction)	Sensitivity assessment source	
Padina pavonica	2	Not Assessed	Not Assessed	MarESA	
Pagurus bernhardus	3	3	4	Sediment	
Palinurus elephas	3	Not Assessed	Not Assessed	MarESA	
Palmaria palmata	2	Not Assessed	Not Assessed	Sublittoral rock	
Paramphinome jeffreysii	2	3	4	Sediment	
Pecten maximus	3	3	4	Sediment	
Pennatula phosphorea	3	3	4	Sediment	
Phaxas pellucidus	3	3	4	Sediment	
Pholas dactylus	2	No Information	Not Assessed	Sublittoral rock	
Phymatolithon calcareum	5	5	5	MarESA	
Polydora ciliata	2	No Information	Not Assessed	Sublittoral rock	

Species	Abrasion/disturbance of the substrate on the surface of the seabed	Penetration and/or disturbance of the substrate below the surface of the seabed, including abrasion	Habitat structure changes - removal of substratum (extraction)	Sensitivity assessment source	
Protodorvillea kefersteini	2	2	4	Sediment	
Sabella pavonina	2	No Information	Not Assessed	Sublittoral rock	
Scoloplos armiger	2	2	4	Sediment	
Sepia officinalis	3	3	3	MarESA	
Sertularia argentea	3	3	3	Sediment	
Spirobranchus triqueter	3	Not Assessed	Not Assessed	Sediment; Sublittoral rock	
Styela gelatinosa	3	3	4	Sediment; Sublittoral rock	
Thyasira flexuosa	3	3	4	Sediment	
Timoclea ovata	3	3	4	Sediment	
Urticina felina	3	3	4	Sediment	

Species	Abrasion/disturbance of the substrate on the surface of the seabed	Penetration and/or disturbance of the substrate below the surface of the seabed, including abrasion	Habitat structure changes - removal of substratum (extraction)	Sensitivity assessment source
Virgularia mirabilis	3	3	4	Sediment

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# References

Bildstein, T., D. Fiorentino, C.-P. Günther, R. Pesch, P. Rückert, W. Schröder, B. Schuchardt (2014): Cluster 6 Biotopkartierung: Endberichtsentwurf - Teil Nordsee. Report on behalf of the Bundesamt für Naturschutz.

BioConsult (2013): Seafloor integrity - Physical damage, having regard to substrate characteristics (Descriptor 6). A conceptual approach for the assessment of indicator 6.1.2: 'Extent of the seabed significantly affected by human activities for the different substrate types'. Report within the R & D project 'Compilation and assessment of selected anthropogenic pressures in the context of the Marine Strategy Framework Directive', UFOPLAN 3710 25 206.

Holling, C, S. (1973) Resilience and Stability of Ecological Systems, Annual Review of Ecology and Systems, **4**, 1-23.

Holt, T.J., Jones, D.R., Hawkins, S.J. & Hartnoll, R.G. (1995). The sensitivity of marine communities to man-induced change - a scoping report. Countryside Council for Wales, Bangor, CCW Contract Science Report, no. 65.

Last, E.K., Matear, L., & Robson, L.M. (2020). Developing a method for broadscale & feature-level sensitivity assessments: the MarESA aggregation. JNCC Report No. 662, JNCC, Peterborough, ISSN 0963-8091.

OSPAR Commission, 2011. Pressure list and descriptions. Paper to ICG-COBAM 11/8/1 Add.1-E (amended version 25th March 2011) presented by ICG-Cumulative Effects. OSPAR Commission, London.

OSPAR Commission, 2014. OSPAR Joint Assessment and Monitoring Programme (JAMP) 2014-2023

OSPAR Commission, 2018. OSPAR Coordinated Environmental Monitoring Programme (CEMP) Guidelines. Common indicator: Condition of benthic habitat communities (BH2) – common approach.

Rachor, E.& Nehmer, P. (2003): Erfassung und Bewertung ökologisch wertvoller Lebensräume in der Nordsee.

Agreement 2017-09 (Update 2023) CEMP Guidelines – Technical Specifications Version 6 October 2022

Rachor, E.; Reiss, H.; Degraer, S.; Duineveld, GCA.; van Hoey, G.; Lavaleye, M.; Willems, W.; Rees, H.L. (2007): Structure, distribution, and characterizing species of North Sea macrozoobenthos communities in 2000. In: Rees HL, Eggleton JD, Rachor E, Berghe E van der (eds): Structure and dynamics of the North Sea benthos. Copenhagen, p 46–59.

Salzwedel, H.; Rachor, E.; Gerdes, D. (1985): Benthic macrofauna communities in the German Bight. -Veröffentlichungen des Institutes für Meeresforschung Bremerhaven 20: 199-267.

Serrano, A., de la Torrientea A., Punzóna, A., Blancoa, M., Bellas, J., Durán-Muñoz, P., Murillo, F.J., Sacau, M., García-Alegrea, A., Antolíneza, A., Elliott, S., Guerine, L., Vina-Herbón, C.V., Marra, S., González-Irustaa, J.M., 2022. Sentinels of Seabed (SoS) indicator: Assessing benthic habitats condition using typical and sensitive species. *Ecological Indicators*, 140, 108979.

Tillin, H.M., S.C. Hull & H. Tyler-Walters (2010): Development of a Sensitivity Matrix (pressures-MCZ/MPA features). Defra Contract No. MB0102 Task 3A, Report No. 22. http://jncc.defra.gov.uk/pdf/MB0102\_Sensitivity\_Assessment%5B1%5D.pdf

Tillin, H. & Tyler-Walters, H., (2014a): Assessing the sensitivity of subtidal sedimentary habitats to pressures associated with marine activities - Phase 1 Report, JNCC Report 512A. *http://jncc.defra.gov.uk/page-6790* 

Tillin, H. & Tyler-Walters, H., (2014b): Assessing the sensitivity of subtidal sedimentary habitats to pressures associated with marine activities - Phase 2 Report, JNCC Report 512B. *http://jncc.defra.gov.uk/page-6929* 

Tillin, H. & Tyler-Walters, H., (2014c): Assessing the sensitivity of subtidal sedimentary habitats to pressures associated with marine activities - Phase 3 Sensitivity Proformas (not published on the JNCC website but can be supplied upon request).

Tillin, H.M. & Tyler-Walters, H. (2015). Finalised list of definitions of pressures and benchmarks for sensitivity assessment. 7-9.

Agreement 2017-09 (Update 2023) CEMP Guidelines – Technical Specifications Version 6 October 2022

Tyler-Walters, H., Tillin, H.M., d'Avack, E.A.S., Perry, F. & Stamp, T., 2018. Marine Evidence based Sensitivity Assessment (MarESA) – A Guide. Plymouth: Marine Biological Association.

Zacharias, M. A. & Gregr, E. J. (2005). Sensitivity and Vulnerability in Marine Environments: an Approach to Identifying Vulnerable Marine Areas. *Conservation Biology.* 19, 86-97.

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# Annex 3- Development of Sensitivity maps

# **General Approach**

The development of sensitivity maps involved creating a sensitivity layer that quantified the sensitivity of species and habitats within the OSPAR Maritime Area to surface and subsurface abrasion pressure. To avoid the potential inclusion of sensitivity data that might represent an already impacted state, a precautionary approach was taken when assessing habitat sensitivity. Where available the evidence used for sensitivity assessments should represent the biogeography of the area. To enable sensitivity assessment at the scale of OSPAR assessment units, sensitivity evidence might need to be sourced from other regions.

Due to the large spatial scale of the indicator, sensitivity information is primarily attributed using the underlying habitat information given by the composite habitat map (see Annex 1). Additionally, *in-situ* species occurrence records (species with assessed sensitivity described in Annex 2) are added, to improve confidence.

#### Method

The BH3 sensitivity map is created from a composite of habitat sensitivity attributed to the composite habitat map and *in-situ* species sensitivities attributed to intersecting habitat polygons. Sensitivity is attributed for each of the given pressures outlined in Annex 2 (surface abrasion, subsurface abrasion, and extraction). Sensitivity maps for bottom-contacting fishing pressure were created to cover the entire OSPAR Maritime Area, sensitivity maps for extraction pressure were only created for licensed extraction areas or where extraction data had been reported.

#### Sensitivity in licensed extraction areas

Spatial licensed area polygons were analysed in Arc Map v10.1 and QGIS v 3.16 Hannover. The data provided by ICES WGEXT contained a comprehensive dataset of licensed extraction areas within the OSPAR Maritime Area. However, these data were supplemented with additional polygons not included by ICES, obtained directly under the OSPAR data call from German experts (outlining two known active sand and gravel extraction sites) and the Fællesområder and Auktionstilladelser layers obtained from the Ministry of Environment for Denmark (MST). Data received directly from France and data available on the European Marine Observation Data Network (EMODnet) were covered by licensed areas in the ICES dataset. Data available on the Niedersächsischen Bodeninformationssystems (NIBIS) data portal and the Efterforskningsområder layer from MST contained licensed areas for other extraction methods (e.g., terrestrial) or outlined exploration sites for aggregate extraction so were not deemed appropriate for the BH3 assessment.

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Data from ICES, Germany, and MST were combined into a single GIS layer and intersected with OSPAR assessment unit polygons, which excluded any licensed areas that occurred outside the OSPAR Maritime Area (e.g., those for Finland and Sweden). Additionally, licensed areas that occurred in assessment units where BH3 is not agreed as a common indicator were removed (Icelandic licensed areas in Region I and Portuguese areas in Region V). Furthermore, two large, licensed areas for shell extraction (covering over 17 000 km<sup>2</sup>), off the coast of The Netherlands in the Southern North Sea, were identified when processing the spatial data. Consultation with Dutch experts, via OSPAR, indicated that these areas outlined the zone between 5 and 50 km from the coast where shell extraction was permitted. In practice, shell extraction activity was confirmed to be negligible, with extracted materials not allowed to exceed levels of natural accretion (Noordzeeloket, 2022). These areas licensed for shell extraction were, therefore, not considered representative of the activity and these two aforementioned areas were removed from the assessment to facilitate a more accurate assessment of typical aggregate extraction licensed areas in the OSPAR Maritime Area.

#### Habitat sensitivity

• Stage one: BH3 habitat sensitivity assessment to defined pressures (as described in Annex 2) were joined to the composite habitat map (Annex 1) using the EUNIS 2007 habitat codes (Figure A3.1). To maximise available data coverage, MB0102 sensitivity assessments were used for habitats that did not have MarESA assessments (A6.1-8).

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Figure A3.1: Example of habitat sensitivity to surface abrasion

#### In-situ species sensitivity

To ensure species records from survey data were not overrepresented in large habitat polygons, the following process was used to create a species data sensitivity layer:

- Stage two: The composite habitat map, with associated habitat sensitivity values added, was spatially intersected to create a gridded habitat sensitivity layer. Intersections were processed using ESRI Arc GIS v10.1 with a 0.05° x 0.05° grid (spatially aligned with ICES c-squares) for surface and subsurface sensitivity layers; and with a 50 m x 50 m grid (spatially aligned with extraction pressure data) for the extraction sensitivity layer. These grid resolutions were chosen to align with the resolution of the VMS or extraction pressure data.
- Stage three: The *in-situ* species points records were spatially joined to individual habitat polygons within a 0.05° x 0.05° grid cells (for surface and subsurface sensitivity) or a 50 m x 50 m grid (for extraction sensitivity). In instances where

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multiple species points overlapped a single habitat polygon within a grid cell, only the maximum species sensitivity value was joined. This created a polygon layer with both habitat and, where available, species sensitivity values (Figure A3.2).



*Figure A3.2: Example of in-situ species sensitivity to surface abrasion mapped to habitat polygons within 0.05° x 0.05° grid cells.* 

#### Combing habitat and species record sensitivity

Habitat and species record sensitivity layers were combined to create a final sensitivity map for a given pressure

• Stage four: Habitat polygons with *in-situ* species sensitivities were first erased from the habitat sensitivity layer and then merged to the output, giving a layer with both habitat and species record sensitivity where present. Final sensitivity to the pressure was then attributed to the habitat polygons. Where *in-situ* species sensitivity was

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present the maximum value between the habitat and species sensitivity was assigned as the final sensitivity value.

 Stage five: Sensitivity layers were intersected and with OSPAR assessment units. For surface and subsurface layers, assessment unit polygons were merged with sensitivity outputs; sensitivity layer erased from assessment unit then merged with output. Joining assessment unit area with sensitivity allowed for the quantification of area without EUNIS habitat information and therefore, area without sensitivity assessments to be analysed as unassessed disturbance when intersected with pressure data (Figure A3.3).



Figure A3.3: Example of a final sensitivity map for surface abrasion pressure, habitat and in-situ species sensitivities combined.

Final sensitivity layers for each assessment unit were processed with the corresponding pressure layers (see Annex 4, 5, and 6).

# Annex 4: Development of surface and subsurface abrasion layers from fishing with bottom-contact gear

# Introduction

When analysing the effects human activities, such as bottom-contact fishing can have on marine environments, it is important to understand the pressures associated with the assessed activity. Pressure can be defined as "the mechanism through which an activity has an effect on any part of the ecosystem", the nature of the pressure is determined by the type of activity, intensity, and its distribution (Robinson *et al.*, 2008). Previous studies have established an evidence base for understanding relationships between human activities and their associated pressures in marine environments via literature review (Defra, 2015; Robson *et al.*, 2018). The two physical pressures associated with bottom-contact fishing selected for this assessment included abrasion / disturbance of the substrate on the surface of the seabed and penetration / disturbance of the substrate below the surface of the seabed (hereafter defined as 'surface' and 'subsurface' abrasion, respectively).

Pressures associated with bottom-contact fishing are categorised by métier-specific penetration depths, dependent on whether they cause surface or subsurface abrasion (JNCC, 2011; Church *et al.*, 2016, ICES, 2021a). Surface abrasion pressure can be caused by fishing gears, including trawling nets and can damage communities on the seafloor surface and upper layers of sediment (< 2 cm in depth). Subsurface abrasion pressure can be caused by gear types including beam trawls and is defined as the penetration of the substrate  $\geq$  2 cm below the surface, potentially damaging communities living within the sediment such as burrowing bivalves. To further understand the effect that these pressures have on parts of the ecosystem, information quantifying fishing intensity (defined as the area swept by fishing gears per unit area) is required (Eno *et al.*, 2013; Eigaard *et al.*, 2016; van Loon, *et al.*, 2018). 'Swept area' is generally considered to be an estimate of the area of seabed in contact with the fishing gear. It is a function of gear width, vessel speed and fishing effort (JNCC 2011).

The predominant activities associated with physical abrasion, in terms of extent and intensity, are 'fishing: demersal trawling' and 'fishing: dredging'. Gear coding in logbooks is not typically suited for quantitative estimation of seafloor pressure (swept area and impact severity). The EU FP7 "BENTHIS" project developed a method to overcome this information deficiency. The approach is to use the relationships between gear dimensions and vessel size (e.g., trawl door spread and vessel engine power (kW)) for different métiers to assign quantitative information on bottom contact (e.g., width of gear). A métier is a group of fishing operations targeting specific species assemblages, using similar fishing gear, throughout a consistent period of time (annually) and/or within the same area; such groups are also characterised by a similar exploitation pattern (Definition from the Data Collection Framework). As part of this project a list of 14 different functional gear categories was created and populated with information on vessel size (m), power (kW) and gear

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specifications for each métier collected in a pan-European industry-based questionnaire survey (Eigaard et al, 2016). Additional improvement of the method can be found in the ICES reports produced as a request from the EU on fisheries management (ICES 2021a and ICES 2021b)

# Gear widths and speeds

Different gear types interact with the seabed in different ways and subsequently exert different levels of abrasive pressure both in terms of the area of substrate affected and the penetration depth. These considerations are central to the recommended method as gear width (determined by gear type) is a key component of the swept area calculation and can contribute differently to the area estimates of surface and subsurface abrasion respectively (Church *et al.*, 2016).

Due to differences in the characteristics of target species, otter trawls, beam trawls and scallop dredges vary in their physical interaction with the seabed. Generally speaking, demersal otter trawls are designed to target fish and invertebrates close to the seabed while beam trawls and scallop dredges target species that live on the seabed or are partially buried in the sediment (Løkkeborg, 2004). Different components of the gear can interact with the seabed in different ways. For instance, for otter trawls, the towed otter doors represent a relatively small spatial footprint but penetrate deeply into the seabed, as opposed to the ground ropes (foot-rope) between the doors which have a much larger spatial footprint, but do not typically penetrate the seabed as deeply (Eigaard et al., 2016, ICES, 2021a). The sweeps/bridles have the largest contact area with the seabed, however, the degree of impact from these components is still poorly understood (Valdemarsen et al. 2007). Subsequently, otter doors have the potential to disturb both subsurface infaunal and epifaunal communities, whereas ground ropes are likely to only disturb surface epifaunal communities. Beam trawling involves the use of a rigid, typically metal, beam to keep the trawl net open instead of hydrodynamic otter boards, and so generally sweeps a smaller total area. Several components on the trawl (shoes, tickler chains, chain mat) are potentially capable of penetrating the seabed across the width of the gear (Bergman and van Santbrink, 2000). The penetration depth of a beam trawl depends on the weight of the gear and the towing speed, but also on the type of substrate (Paschen et al., 2000). Similarly, scallop dredges are specifically designed to disturb the seabed surface and penetrate the upper few centimetres of the sediment with dredge teeth mounted along the whole width of the gear (Løkkeborg, 2004). The lists of gear groups (based on the level 4 classification of fishing gears), including the range of values for width and speed used can be found at Church et al (2016), and for the metiers in Eigaard et al, (2015) and ICES (2021a)

# **Data Overview**

Two types of data may be used for this method:

- Anonymised VMS 'ping' data; or
- Aggregated VMS data grids.

Anonymised VMS 'ping' data are not currently available to all data users, due to their commercially sensitive nature. Data are sometimes aggregated to a grid before release to anonymise the movements of individual fishing vessels. Both 'ping' and gridded data are considered to make the approach relevant to most users.

To create a swept area abrasion data layer at the OSPAR Regional scales, the method needs to be applied to all gridded VMS data submitted by participating countries. Please note that for the years 2009–2011 VMS was mandatory for fishing vessels larger than 15 m and during the years 2012/2013 VMS was mandatory for fishing vessels larger than 12 m. For a number of reasons, not all vessels in the 12–15 m category were VMS-enabled by 2013 so it is likely that more vessels will transmit data in this size class over the coming years.

#### Swept area

The area of seabed swept by a vessel was calculated per gear type per annum. The swept area method can be applied to both aggregated VMS and VMS pings. This calculation was carried out for each demersal and dredging fishing gear type:

- For the VMS pings, 'Swept area', SA, (m<sup>2</sup>) can be calculated per ping, multiplying the 'width of fishing gear', w, (m) by the 'recorded speed', v, (m.min<sup>-1</sup>) and the 'time fished' (each ping representing the area swept since the last recorded ping), e, (min) to get an estimate of area covered per gear, per ping (Equation A4.1). The pings were then aggregated by summing on a grid at 0.05 <sup>0</sup> x 0.05 <sup>0</sup> (which aligned with the aggregated VMS data). The resulting swept area was calculated as m<sup>2</sup>, per cell, per annum (m<sup>2</sup>.cell<sup>-1</sup>.yr<sup>-1</sup>)
- 2. For aggregated data the area of seabed swept by a vessel was calculated per Benthis métier group (gear type in absence of metier, see ICES, 2015 Table 4.3.1.2.1.) per annum and based on the abrasion methodology proposed by ICES WG SFD (2015) and Church *et al.*, 2016. The fishing area swept (Swept Area) was calculated per grid cell (m<sup>2</sup>.cell<sup>-1</sup>). It was calculated by multiplying the values of bottom contact, *w*, (m) by the 'average vessel speed' *v*, (m.hr<sup>-1</sup>) for the relevant métier, and the 'time fished', *e*, (hour) to get an estimate of area covered per gear (Equation A4.1). The final output is calculated as area swept per cell, per annum (m<sup>2</sup>.cell<sup>-1</sup>.yr<sup>-1</sup>). This is aggregated across métiers for each gear class (Otter trawl, Beam trawl, Dredge and Demersal seine) per year and across years. Two fields are produced for each gear class; one for 'surface' abrasion and one for 'subsurface' abrasion.

Equation A4.1 Swept Area calculation

$$SA = \sum e_{VW}$$

Where SA is the swept area, e is the number of minutes between pings, w is total width of fishing gear (m) causing abrasion, v is average speed vessel (m/min)

A swept-area ratio, *SAR*, was calculated to account for the varying cell size of the GCS WGS84 grid. To produce the swept-area ratio (i.e., area swept in terms of the proportion of the cell fished within the time period, measured as a ratio of the area of the cell), *SA* was divided by the actual grid cell area, *CA* (Equation A4.2).

Equation A4.2: Swept-Area 3.4.1 ratio calculation

$$SAr = \frac{SA}{CA}$$

Where SA is the swept area, CA is cell area and SAR is swept area ratio (number of times the cell was swept).

For both datasets, two standardised GIS layers were created per year; one for 'surface' abrasion and one for 'subsurface' abrasion.

#### Steps for the data analysis

The method for the analysis of the VMS data includes several steps. These have been developed by the ICES Working group on Spatial Fisheries data, using the OSPAR data call through ICES on VMS and logbook data, but they are equally applicable to any dataset that contains VMS data. For an overview of the steps and data analysis see ICES 2021a.

A workflow and an R-script were developed to calculate fishing intensity for the assessment period 2009 to 2020 (code available at: https://github.com/ices-taf/2021\_2007-36\_SpecialRequest).

#### Annual pressure maps:

The analysis of annual VMS data provided by ICES were used to create the surface and subsurface pressure categories based on their respective swept area ratio values. Trawling effort was categorised using an intensity scale ranging from 'none' to 'very high' (cell area swept more than 300% or 3 times per year). The current scales for the classification of the fishing intensity are shown in Table A4.1, and mapped in Figure A4.1.

The criteria for developing the pressure scale were as follows:

- The distribution of fishing pressure in the OSPAR area should be adequately shown
- Areas with lower fishing pressure (SAR <1) should be distinguished as well as areas with higher fishing pressure

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- It should be based on a scientifically justifiable approach.

Several data-driven approaches have previously been tested for the creation of pressure maps based on VMS logbook data, such as quantiles, standard deviation, natural breaks. However, such approaches showed good differentiation either of the lower SAR values (SAR<1) or of the higher values. However, both the lower and higher values needed to be adequately represented. Additionally, data-driven approached produced different pressure scales for surface and subsurface abrasion when a common scale for both abrasion pressures was required.

The agreed BH3 method therefore uses an intensity scale with 5 categories created based on a literature review of the impacts of fishing activity on benthic ecosystems. Previous studies have shown that one fishing event per year is considered to have high impacts on species abundance (Schroeder *et al.*, 2008). Additionally, significant biological responses to fishing activity have been observed from between 0.15 and 1 fishing event per year (van Loon 2018). Furthermore, areas that were fished more than three times per year did not show any further levels of degradation (van Loon *et al.*, 2018). Therefore, SAR values between 0 and 1 were split into three categories, and an upper category of SAR equivalent to more than 3 was set.

As SAR values of up to 98 were observed in the ICES VMS data, and van Loon et al., (2018) indicated further degradation was not evident beyond three sweeps per year, the intensity scale adopted here allows for differentiation in lower SAR values where the greatest impact on benthic ecosystems has been observed. However, future BH3 assessments will aim to further improve the method of assessing bottom contact fishing pressure as new evidence becomes available.

The aggregation of fishing vessel data to c-squares limited the confidence of the intensity of pressure at a greater resolution when potential fishing pressure may have been more locally focused within a c-square. It was also expected that some pressure data may have been missing due to different approaches for extracting data from national databases. Data gaps also existed for fishing vessels with less than <12 m and <15 m before 2012 in length. This was an important consideration for inshore waters, where smaller vessels were most likely to operate. The inclusion of Inshore Vessel Monitoring Systems (I-VMS) data in future assessments would help address these knowledge gaps.

Table A4.1: Classification of the swept area ratios per gird cell for a year. Note, BH3 category  $0^* = 0$  SAR value reported by ICES for vessels >12 m only.

BH3 Category	SAR
None (0*)	0.00
Very Low (1)	>0.00 - ≤0.33
Low (2)	>0.33 - ≤0.66
Medium (3)	>0.66- ≤1.00
High (4)	>1.00- ≤3
Very High (5)	> 3.00

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Figure A4.1: Example of subsurface abrasion pressure for 2020. Note, BH3 category  $0^* = 0$  SAR value reported by ICES for vessels >12 m only.

# Representing pressure across assessment periods

An aggregated assessment of fishing intensity was required to quantify fishing pressure over a specified reporting period (QSR: 2009 to 2020, MSFD: 2016 to 2020). Previously, methods

such as linear regression models were trialled to analyse variability in fishing pressure over time. However, reporting periods that the BH3 indicator may be used for are of varying length and analyses techniques, such as linear regression models, were not appropriate for short time periods of data. Therefore, the range of SAR categories observed across the time series was calculated for each c-square, indicating distinction between areas where fishing intensity was at 'Consistent' levels across years, from those where fishing intensity levels were 'Variable'. C-squares were considered 'Variable' if a range of three or more SAR categories was observed throughout the time series. C-squares that had a variance range of three or more SAR categories were used to indicate areas of opportunistic fishing, potentially new areas being explored for fishing or areas which were not used consistently.

The approach for creating aggregated fishing pressure maps was therefore as follows (Please see supplementary R script for full detail on the methods used):

- Step 1 Combining annual VMS pressure layers: Annual VMS data layers were combined into a single spatial layer using the 'Union' tool in ArcMap v10.1 (ESRI, 2012). However, in c-squares where VMS data was reported at some stage in the assessment period, the 'Union' created false 0 values where VMS data was not reported for a particular year or years. These 0 values were considered false due to being an artifact of the 'Union' and, therefore, differed to 0 SAR values submitted in the ICES VMS dataset. These false 0 values and subsequent VMS pressure data analyse were carried out in R (versions ranging from 3.6.1 4.1.2; R core team 2019-2021) using the tidyverse (Wickham *et al.*, 2019), sf (Pebesma, 2018), and rgdal (Bivand *et al.*, 2021) packages.
- Step 2 Amending false zero values in the united pressure layer: False zero values in the united VMS layer created in Step 1 were amended to NAs to omit them from further calculations to ensure the data was not inaccurately skewed.
- Step 4 Quantifying variance over time for a given reporting period: The variance in fishing pressure within individual c-squares was quantified by calculating the range in SAR categories observed across the assessment period. C-squares with a range in three or more SAR categories were considered to be under 'Variable' levels of fishing pressure. C-squares with a range of less than three SAR categories were considered to be under a 'Consistent' level of fishing pressure.
- Step 5 Calculating final aggregated SAR categories representative of fishing pressure for the assessment period: For 'Variable' c-squares, the maximum uncategorised SAR value was assigned as the aggregated SAR value representative of the assessment period. For 'Consistent' c-squares, the mean uncategorised SAR value across the assessment period was assigned as the aggregated SAR values representative of the assessment period. Final SAR values were then recategorized into the intensity scale outlined in Table A4.1.

Final aggregated pressure categories for each assessment period (e.g., Figure A4.3) were used to calculate disturbance representative of the period.



Figure A4.3. Aggregated Surface abrasion pressure using 2009-2020 data series. Note, BH3 category  $0^* = 0$  SAR value reported by ICES for vessels >12 m only.

# References

Barnard, S. & Boyes, S.J, (2013), *Review of Case Studies and Recommendations for the Inclusion of Expert Judgement in Marine Biodiversity Status Assessments*, JNCC Report 490, JNCC, Peterborough.

Bergman, M.J.N., van Santbrink, J.W. (2000) Fishing mortality of populations of megafauna in sandy sediments. In: Kaiser MJ, de Groot SJ (eds) Effects of fishing on non-target species and habitats: biological, conservation and socio-economic issues. Blackwell Science, Oxford, p 49–68.

Bivand, R., Keitt, T., and Rowlingson, B. (2021). rgdal: Bindings for the 'Geospatial' Data Abstraction Library. R package version 1.5-23. https://CRAN.R-project.org/package=rgdal

Church N.J., Carter A.J., Tobin D., Edwards D., Eassom A., Cameron A., Johnson G.E., Robson, L.M. & Webb K.E. (in prep) JNCC Recommended Pressure Mapping Methodology 1. Abrasion: Methods paper for creating a geo-data layer for the pressure 'Physical Damage (Reversible Change) - Penetration and/or disturbance of the substrate below the surface of the seabed, including abrasion'. JNCC report No. 515, JNCC, Peterborough.

Defra, 2015. Validating an Activity-Pressure Matrix. Report R.2435.

Dernie, K. M. (2003). *Predicting Recovery of Soft Sediment Communities Following Physical Disturbance.* School of Ocean Sciences, University of Wales, Bangor.

Dinmore, T., Duplisea, D. E., Rackham, B. D., Maxwell, D. L. & Jennings, S. (2003). Impact of a large-scale area closure on patterns of fishing disturbance and the consequences for benthic communities. *ICES Journal of Marine Science*, **60**, 371-380.

Eastwood, P. D., Mills, C. M., Aldridge, J. N., Houghton, C. A. & Rogers, S. I. (2007). Human activities in UK offshore waters: an assessment of direct, physical pressure on the seabed. ICES Journal of Marine Science, **64**, 453-463.).

Eigaard Ole R., Bastardie F., Breen M., Dinesen G. E. 1, Hintzen N. T., Laffargue P., Mortensen L. O., Nielsen J. R., Nilsson H. C., O'Neill F. G., Polet H., Reid D. G., Sala A., Skold M., Smith C., Sørensen T. K., Tully O., Zengin M., and Rijnsdorp A. D. (2015). Estimating seabed pressure from demersal trawls, seines, and dredges based on gear design and dimensions. ICES Journal of Marine Science, **73**, i27-i43. doi:10.1093/icesjms/fsv099 Eno, N. C., Frid, C. L. J., Hall, K., Ramsay, K., Sharp, R. A. M., Brazier, D. P., Hearn, S. (2013). Assessing the sensitivity of habitats to fishing: from seabed maps to sensitivity maps. Journal of Fish Biology, 83: 826–846.

ESRI, 2012. ArcGIS Release 10.1. Redlands, CA.

III.pdf

Foden, J., Rogers, S. I. & Jones, A. P. (2010). Recovery of UK seabed habitats from benthic fishing and aggregate extraction - towards a cumulative impact assessment. *Marine Ecology Progress Series*, **411**, 259–270.

Foden, J., Rogers, S. I. & Jones, A. P. (2011). Human pressures on UK seabed habitats: a cumulative impact assessment. *Marine Ecology Progress Series*, **428**, 33–47.

Gerritsen, H. D., Minto, C., & Lordan, C. (2013). How much of the seabed is impacted by mobile fishing gear? Absolute estimates from Vessel Monitoring System (VMS) point data. *ICES Journal of Marine Science*.

Halpern, B. S., Walbridge, S., Selkoe, K. A., Kappel, C. V., Micheli, F., D'Agrosa, F. *et al.* (2008). A Global Map of Human Impact on Marine Ecosystems. *Science*, **319**, 948-952.

Hinz, H., Murray, L.G., Lambert, G.I., Hiddink, J.G. & Kaiser, M.J. (2012). Confidentiality over fishing effort data threatens science and management progress. Fish and Fisheries, **14**, 110–117. doi: 10.1111/j.1467-2979.2012.00475.x

ICES (2010). *Manual for the International Bottom Trawl Surveys (revision VIII)*. Retrieved May 17, 2012, from ICES: http://datras.ices.dk/Documents/Manuals/Addendum\_1\_Manual\_for\_the\_IBTS\_Revision\_V

ICES (2015). Report of the Working Group on Spatial Fisheries Data (WGSFD). http://www.ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Report/SSGEPI/

2015/01%20WGSFD%20-

% 20 Report % 20 of % 20 the % 20 Working % 20 Group % 20 on % 20 Spatial % 20 Fisheries % 20 Data.pdf

ICES (2021a). A series of two Workshops to develop a suite of management options to reduce the impacts of bottom fishing on seabed habitats and undertake analysis of the trade-offs between overall benefit to seabed habitats and loss of fisheries revenue/contribution margin for these options (WKTRADE3). ICES Scientific Reports. 3:61. 100 pp. http://doi.org/10.17895/ices.pub.8206

ICES (2021b). ICES advice to the EU on how management scenarios to reduce mobile bottom fishing disturbance on seafloor habitats affect fisheries landing and value. In Report of the ICES Advisory Committee, 2021. ICES Advice 2021. sr.2021.08. https://doi.org/10.17895/ices.advice.8191. ICES (2021c). OSPAR request on the production of spatial data layers of fishing intensity / pressure. *ICES Technical service.* 

Jennings, S., Alvsvag, J., Cotter, A. J., Ehrish, S., Greenstreet, S. P., Jarre-Teichmann, A., *et al.* (1999). Fishing effects on the northeat Atlantic shelf seas:patterns in fishing effor, diversity and sommunity structure. III. International trawling effort in the North Sea: an analysis of spatial and temporal trends. *Fisheries Research*, **40**, 125-134.

Jennings, S., Lee, J., & Hiddink, J. G. (2012). Assessing fishery footprints and trade-offs between landings value, habtat sensitivity, and fishing impacts to inform marine spatial planning and an ecosystem approach. *ICES Journal of Marine Science*, 1-11.

JNCC (2011). *Review of methods for mapping anthropogenic pressures in UK waters in support of the Marine Biodiversity Monitoring R&D Programme.* Briefing paper to UKMMAS evdience groups. Presented 06/10/2011.

Korpinen, S., Meski, L., Andersen, J. H., & Laamanen, M. (2012). Human pressures and their potential impact on the baltic sea ecosystem. *Ecological Indicators*, **15**, 105-114.

Krost, P., M. Bernhard, F. Werner, & W. Hukriede. 1990. Otter trawl tracks in Kiel Bay (Western Baltic) mapped by side-scan sonar. *Meeresforsch*, **32**,344-353.

Lee, J., South, A., & Jennings, S. (2010). Developing reliable, repeatable, and accessible methods to provide high-resolution estimates of fishing-effort distributions from vessel monitoring system (VMS) data. *ICES Journal of Marine Science*, **67**, 1260–1271.

Løkkeborg, S. (2004) Impacts of trawling and scallop dredging on benthic habitats and communities. FAO fisheries technical paper 472.

Mills, C. M., Townsend, S. E., Jennings, S., Eastwood, P. D., & Houghton, C. A. (2007). Estimating high resolution trawl fishing effort from satellite-based vessel monitoring system data. *ICES Journal of Marine Science*, **64**, 248–255.

Paschen, M., U. Richter, W. Kopnick, U. Lorenzen, M. Zimmermann, R. Fonteyne, B. Van Marlen & S. de Groote (2000). Trawl Penetration of the Sea-bed (TRAPESE); contract number 96-006; [final report ; research project financed by the European Community, Directorate General XIV - Fisheries]. Rostock, Rostock Inst. für Maritime Systeme und Strömungstechnik.

Pebesma, E. (2018). Simple Features for R: Standardized Support for Spatial Vector Data. *The R Journal* 10 (1), 439-446.

Piet, G. J., Quirijns, F. J., Robinson, L., & Greenstreet, S. P. (2006). Potential pressure indicators for fishing, and their data requirements. *ICES Journal of Marine Science*, **64**, 110–121.

Version 6 October 2022

R Core Team (2019). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org//.

R Core Team (2020). R: A language and environment for statistical computing. *R Foundation for Statistical Computing, Vienna, Austria*. Available at https://www.R-project.org/.

R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available at https://www.R-project.org/.

Robinson, L.A., Rogers S. & Frid, C.L.J. (2008). A marine assessment and monitoring framework for application by UKMMAS and OSPAR - Assessment of Pressures and Impacts. Phase II: Application for regional assessments. JNCC Contract No: C-08-0007-0027. UKMMAS, 2010. Charting Progress 2.

Robson, L.M., Fincham, J., Peckett, F.J., Frost, N., Jackson, C., Carter, A.J. & Matear, L. 2018. UK Marine Pressures-Activities Database "PAD": Methods Report. JNCC Report No. 624, JNCC, Peterborough, ISSN 0963-8091.

Rose, C., Carr, A., Ferro, D., Fonteyne, R., & Macmullen, P. (2000). Using Gear Technology to Understand and Reduce Unintended Effects of fishing on the Seabed and Associated Communities: background and potential directions. Retrieved May 17, 2012, from ICES: http://www.ices.dk/products/CMdocs/2000/B/B0300.pdf

Schroeder, A., L. Gutow & M. Gusky (2008): FishPact. Auswirkungen von Grundschleppnetzfischereien sowie von Sand- und Kiesabbauvorhaben auf die Meeresbodenstruktur und das Benthos in den Schutzgebieten der deutschen AWZ der Nordsee (MAR 36032/15). Report for the Federal Agency for Nature Conservation.

Van Loon, W.M.G.M., Boon, A.R., Gittenberger, A., Walvoort, D.J.J., Lavaleye, M., Duineveld, G.C.A., Verschoor, A.J., 2015. Application of the Benthic Ecosystem Quality Index 2 to benthos in Dutch transitional and coastal waters, Journal of Sea Research, Volume 103, 1-13.

Van Loon, W.M.G.M., Walvoort, D.J., Van Hoey, G., Vina-Herbon, C., Blandon, A., Pesch, R., Schmitt, P., Scholle, J., Heyer, K., Lavaleye, M. and Phillips, G., 2018. A regional benthic fauna assessment method for the Southern North Sea using Margalef diversity and reference value modelling. Ecological Indicators, 89, 667-679.

Valdemarsen, J., Jorgensen, T., & Engas, A. (2007). *Options to Mitigate Bottom Habitat Impact of Dragged Gear.* Retrieved May 17, 2012, from FOA: ftp://ftp.fao.org/docrep/fao/010/a1466e/a1466e.pdf

Wickham, H., Averick, M., Bryan, J., Chang, W., McGowan, L.D.A., François, R., Grolemund, G., Hayes, A., Henry, L., Hester, J., Kuhn, M., Pedersen, T., Miller, E., Bache, S., Müller, K., Ooms, J., Robinson, D., Seidel, D., Spinu, V., Takahashi, K., Vaughan, D., Wilke, C., Woo, K. and Yutani, H., (2019). Welcome to the tidyverse. *Journal of Open-Source Software*, 4(43), 1686.

# Annex 5: Development of physical disturbance pressure layers for nonfishing activities

# Aggregate extraction<sup>1</sup>

# Introduction

Aggregate extraction is an important pressure affecting the seabed and was chosen as the first nonfishing activity to be added as an additional pressure layer for physical damage. Aggregate extraction practices in UK waters were used as the primary source of information in the development of the pressure layer. In the UK aggregate extraction is primarily undertaken using trailer dredging, anchor dredging typically occurs inshore for capital and maintenance purposes with limited data available. The method proposed focuses on trailer dredging and was initially limited to the United Kingdom with data from the Crown Estate. Additional data provided Denmark was also incorporated, however due to variations in aggregate industry practices and data format, these data were processed differently than those supplied by the United Kingdom. The pressure layers aim to represent the physical damage caused by aggregate extraction gear in contact with the seabed, they do not aim to assess habitat loss or secondary impacts (e.g., sediment resuspension).

# Method:

# Data sources

The extraction data analysed were collated via a joint EIHA and BDC data call, circulated in June 2021. The data call aimed to facilitate standardised and regionally comparable assessments of physical disturbance associated with aggregate extraction on benthic habitats, within the OSPAR Maritime Area. Data were requested from all OSPAR Regions in the formats of:

- 1. Licensed extraction areas and;
- Gridded extraction data, as either;
   2a. total volume dredged, per licensed extraction area/per grid cell, and / or;
   2b. extraction duration in units of time per grid cell as gridded spatial data, indicative of the activity intensity, including both vessel Automatic Identification System (AIS) and Electronic Monitoring System (EMS) data.
- 3. Confirmation of OSPAR Contracting Parties where aggregate extraction activity was known not to occur.

To align with wider North-East Atlantic-scale assessments of aggregate extraction, such as those conducted by the ICES Working Group on the Effects of Extraction of Marine Sediments on the Marine Ecosystem (ICES-WGEXT), data were requested in a standardised 50 m x 50 m grid format. Grids of 50 m x 50 m are beneficial for assessing aggregate extraction data as they equate to the frequency of vessel EMS / AIS pings (typically every 20–30 seconds) (ICES, 2019a). Additionally, the OSPAR QSR presented a temporal assessment of pressure, which required annual gridded data to spatially align. Therefore, the data call requested that 50 m x 50 m grids aligned with parameters derived from European Environment Agency Reference Grids and Infrastructure for Spatial Information in Europe (INSPIRE) geographical grid systems, which previously facilitated standardised reporting on progress

<sup>&</sup>lt;sup>1</sup> Please note that additional activities will be added in the next phase of indicator development

and the implementation of the Marine Strategy Framework Directive and Article 17 of the Habitats Directive (EEA, 2017):

- Data projected in Lambert Azimuthal Equal-Area projection ETRS89 / EPSG:3035
- Alignment parameters:
  - O Latitude of origin 52° N,
  - O Longitude of origin 10° E,
  - o False northing 3 210 000.0 m,
  - o False easting 4 321 000.0 m,
  - O Grid origin of 0 m N, 0 m E.

Data were received in response to the data call from both OSPAR Contracting Parties and ICES-WGEXT in a range of formats (**Table A5.1**). Overall, the most commonly available data across the OSPAR Maritime Area were boundary polygons of areas licensed for aggregate extraction; polygons were available from direct data call responses and publicly available portals (EMODnet, 2021b; MST, 2021; NIBIS, 2021). In addition, many Contracting Parties submit annual aggregate extraction data to ICES, who collated these data and provided it to OSPAR for analysis in the QSR. Data provided by ICES included: national extraction statistics in the form of volume extracted per country, per conventional sea, per extraction method; spatial polygon layers outlining areas licenced for aggregate extraction; and spatial polygons of areas where extraction occurred within licensed areas for Belgium and the United Kingdom. However, as part of the OSPAR data call additional higher spatial resolution data on volume of sediment extracted was also provided by Germany at the scale of individual licensed areas. Additionally, Denmark and the United Kingdom provided more detailed annual extraction intensity.

Table A5.1: Summary of data received from OSPAR aggregates data call. Spatial data used in the BH3 assessment is highlighted in purple. <sup>1</sup> Preliminary data or a database that is still under construction; <sup>2</sup> The temporal range is applicable to the dataset and not necessarily all individual Contracting Parties within the dataset; <sup>3</sup> Conventional sea not provided in attribute table but spatial analyses indicated that licensed areas were outside the OSPAR Maritime Area; <sup>4</sup> The years 2016, 2018 and 2019 were missing; <sup>5</sup> Only data from 2017 was present for Belgium;' <sup>6</sup> Convention area not supplied within dataset these countries are known to not contain extraction activity within the OSPAR Maritime Area; <sup>7</sup> Temporal range and Contracting Parties summarised in the table were for the OSPAR Maritime Area only; <sup>8</sup> Extraction volumes in IE and SE were zero indicative that there is no aggregate extraction activity from these countries in the OSPAR Maritime Area.

Data Type	Format	Data Provider	Contents	Temporal Range	OSPAR Regions Covered	OSPAR Contracting Parties Covered
Licensed area polygons	Spatial	ICES <sup>1</sup>	Polygons by year and country	1998- 2020 <sup>2</sup>	I, II, III, IV, V	BE, DK, FI <sup>3</sup> , FR, IS, NE, NO, PT, ES, SE <sup>3</sup> , UK
		DE	Polygons for two known active licensed areas for sand and gravel extraction: Westerland III, OAM III	N/A	II	DE
		FR	Polygon layer	N/A	II, IV	FR
		NIBIS portal	Polygon for licensed marine and terrestrial extraction sites for a variety of extraction activities.	N/A	II	DE

Data Type	Format	Data Provider	Contents	Temporal Range	OSPAR Regions Covered	OSPAR Contracting Parties Covered
		MST portal	<ul> <li>Four polygon layers as follows:</li> <li>Fællesområder: Common sites (with multiple license holders)</li> <li>Auktionstilladelser: Exclusive sites with a single user (won on at auction)</li> <li>Bygherretilladelser: Exclusive sites, connected to a specific large building project</li> <li>Efterforskningsområder: sites where exploration and EIA is occurring in preparation for license application</li> </ul>	N/A		DK
		portal <sup>1</sup>	Polygon layers by year by country	constructio	database n	still under
Area extracted polygons	Spatial	ICES <sup>1</sup>	Polygons by year and country	1993- 2024	11, 111	BE⁵, UK
Area extracted values	Tabular	ICES <sup>1</sup>	Annual values for total area licensed and total area dredged per country	2006- 2018	Unknown	BE, DK, FI <sup>6</sup> , FR, IS, NE, SE <sup>6</sup> , UK
Extraction volume (national statistic)	Tabular	ICES <sup>1</sup>	Annual records by country, convention area and extraction type <sup>7</sup>	2005- 2020 <sup>2</sup>	I, II, III, IV, V	BE, DK, FR, DE, IS, IE <sup>8</sup> , NE, NO, PT, ES, SE <sup>8</sup> , UK
Extraction volume (licensed area)	Tabular	DE	Annual records for the following licensed areas: Westerland III, OAM III	2010- 2020	II	DE
Extraction duration	Spatial	The Crown Estate and Royal Haskoning	Annual duration of extraction within 50 x 50 m polygons derived from EMS	2009- 2020	11, 111	UK
Extraction polylines	Spatial	MTS	Annual extraction polylines derived from AIS with associated start and end times and start and	2015- 2020	II	DK

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Data Type	Format	Data Provider	Contents	Temporal Range	OSPAR Regions Covered	OSPAR Contracting Parties Covered
			end speeds from extraction activity			

The degree to which the types of received extraction data could be analysed via BH3 varied, based on data type and resolution of detail (**Table A5.2**). All data received provided valuable insight to the extent of extraction activity within the OSPAR Maritime Area. However, two data sources contained sufficient information to quantify both extent and intensity of pressure and, therefore, estimate disturbance: extraction duration data submitted by the United Kingdom and extraction polyline data submitted by Denmark. However, the spatial extent of these data sources within the OSPAR Maritime Area was limited to just two Contracting Parties. Although other Contracting Parties likely had similar datasets, they were not available for assessments due to commercial sensitivities and constraints from the various national industries. In contrast, licensed area data was the most widespread data available, providing information on the spatial extent of where pressure had potentially occurred across several OSPAR Contracting Parties. Therefore, extraction duration and extraction polyline data from the United Kingdom and Denmark, respectively, were used to estimate disturbance, and licensed area data was used to outline where pressure had potentially occurred. To safeguard commercially sensitive information, raw extraction duration and polyline data from the United Kingdom and Denmark, respectively, were assigned pressure categories prior to disturbance assessments.

Metric	Advantages	Disadvantages
Licensed area polygons (m <sup>2</sup> )	Data available for many countries, indicative of area potentially impacted by pressure	May overestimate footprint as extraction does not occur across whole license area and no measurement of intensity provided.
Area extracted polygons	Provided more accurate representation of area impacted by activity than licensed area alone.	No measurement of intensity. No indication of extraction method provided. Only available for Belgium and the United Kingdom. Only 2017 data provided for Belgium and time series incomplete for the United Kingdom (missing 2016, 2018 and 2019). Please note, data availability assessed at time of QSR assessment, based on data call responses. Data have since been made available post-QSR assessment and will be considered in future assessments: https://rconnect.cefas.co.uk/connect/#/apps/26/access
Area extracted values (m <sup>2</sup> )	Data available for many countries. Indicative of area impacted by pressure for each country.	No spatial information so it is unknown where within licensed areas the pressure has occurred. For countries with EEZs that extend beyond the OSPAR Maritime Area, no indication of conventional sea is given.
Volume extracted (National statistic) (m <sup>3</sup> /m <sup>2</sup> /yr.)	Available for many countries. Facilitated understanding of the annual volume extracted by different extraction activities in different countries. Conventional sea that extraction occurred in was provided.	No spatial information to indicate what licensed areas the volumes extracted were taken from. Number of years provided for each country varied.

Table A5.2 Critical analysis, including advantages and disadvantages of data received in response to OSPAR data call.

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Metric	Advantages	Disadvantages	
Extraction volume (licensed area) (m <sup>3</sup> /m <sup>2</sup> /yr.)	Facilitated understanding of the volume extracted within a given licensed area.	Without direct footprint data, cannot indicate where within a given licensed area is impacted. Data was also only available for Germany.	
Extraction duration (mins/year in 50 x 50 m grid)	Provided information on the extent of where pressure occurred within licensed areas to the resolution of 50 m x 50 m grids derived from EMS data. Annual duration values provided a measurement of intensity of pressure. Complete time series for QSR assessment period (2009 to 2020)	No information on the area impacted within the 50 m x 50 m grid due to commercial data sensitivity. Duration not directly representative of the volume extracted, likely dependent on extraction method. Raw duration data cannot be shared publicly, due to commercial sensitivity. Only available for the United Kingdom.	
Extraction polylines	Provided track lines indicative of extent of aggregate extraction activity derived from AIS pings. Measurements of intensity possible from the data included: duration calculated from start and end times of extraction; length and numbers of polylines with licensed areas; length and numbers of polylines within 50 m x 50 m grid cells.	Extraction polylines not directly representative of the volume extracted, likely dependent on extraction method. Data in raw format and still required substantial sorting. Raw data could not be shared due to commercial sensitivity. Only available for Denmark. Data only available for 2015 to 2020 so not suitable for a full QSR assessment of 2009 to 2020.	

#### Data Analyses

#### Pressure Data Preparation: United Kingdom

United Kingdom extraction data was analysed in R (versions ranging from 3.6.1 - 4.1.2; R core team 2019-2021) using the tidyverse (Wickham et al., 2019) and sf (Pebesma, E., 2018) packages. Aggregate extraction intensity was estimated from calculating the Swept Area Ratio (proportion of a grid cell swept per year, SAR) using **Equation A5.1**.

**Equation A5.1**: Swept Area Ratio (SAR) calculation for aggregate extraction.  $SAR = \frac{Duration \times Draghead \ width \ \times Vessel \ speed}{Area \ of \ grid \ cell}$ 

Where:

- Duration is the annual length of time spent undertaking aggregate extraction (hrs/yr.);
- *Draghead width* is the width of the equipment on the end of the dredge pipe that is in contact with the seabed whilst extracting aggregates (km);
- Vessel speed is the speed at which the vessel is travelling whilst extracting aggregate (km/hr);
- *Area of grid cell* is the grid or cell area determined by the resolution of the data (km<sup>2</sup>).

Fixed values, derived from literature relevant to extraction activity in the North-East Atlantic, were used for the parameters of vessel speed (2 kt, converted to 3.704 km / hr) and draghead width (3 m, converted to 0.003 km) (Kenny & Rees, 1994; Boyd *et al.*, 2003; Boyd & Rees, 2003; Vlasblom, 2005; BMAPA, 2010; Birchenough *et al.*, 2010; Cook & Burton, 2010; Tillin *et al.*, 2011; Last *et al.*, 2011; Drabble, 2012; Newell & Woodcock, 2013; BMAPA, 2017; Robson *et al.*, 2018; **Table A5.3**). The parameters used when calculating SAR are associated with trailer dredging, which was considered the most prevalent method across the OSPAR Maritime Area. Although other forms of extraction, such as static dredging, were known to occur in the North-East Atlantic, available data from the United
Kingdom were not sufficiently detailed to identify specific extraction methods; improved data resolution will be considered in future assessments to improve the accuracy of results. SAR values were then categorised into an intensity scale ranging from 1 to 5 (**Table A5.4**) to create annual extraction pressure maps for the years 2009 to 2020.

Table A5 3. Summary	of trailer dredaina	extraction activity	narameters deriv	od from literature
rubic rus.s. summury	of tranci areaging	chuldellon activity	purumeters acriv	.a ji onn nicci acai c.

Maximum draghead / furrow width (m)	Source information
1.4	Drabble, 2012 (draghead width)
2.4	Drabble, 2012 (furrow)
2.5	Boyd <i>et al.,</i> 2003
3	Kenny & Rees 1994; Boyd & Rees, 2003; Cook & Burton, 2010; Tillin <i>et al.</i> , 2011; Last <i>et a</i> l., 2011; Newell & Woodcock, 2013; BMAPA, 2017; Robson <i>et al.</i> , 2018
4	BMAPA, 2010; Birchenough <i>et al.</i> , 2010
Vessel speed	Source information
1.5 knots	Tillin <i>et al.</i> , 2011; Last <i>et al.</i> , 2011; Newell & Woodcock, 2013; BMAPA, 2017
2 knots	Boyd <i>et al.,</i> 2003; Drabble, 2012
2-3 knots	Vlasblom, 2005

Table A5.4: Categories for BH3 pressure map and associated Swept Area Ratio thresholds (From BH3 OSPAR CEMP guidelines, (OSPAR, 2017).

Pressure category	Pressure score	Swept Area Ratio range
None	0	0
Very Low	1	>0.00 - ≤0.33
Low	2	>0.33 - ≤0.66
Medium	3	>0.66- ≤1.00
High	4	>1.00- ≤3
Very High	5	> 3

#### Pressure Data Preparation: Denmark areas

The method used to process Danish AIS data differed from that used for data supplied by the United Kingdom (duration dredging); vessel track data enabled greater resolution of coverage within a given grid cell than duration alone. Additionally, the high prevalence of static dredging activity in Danish waters could lead to overestimation of the area of seabed impacted if SAR calculations were proportional to dredging time. The approach used aimed to best represent swept area of the seabed, independent of dredge time and vessel speed. This approach may underrepresent additional impacts from static extraction activity which are potentially better represented by total time dredging, such as smothering. However, for the assessment of physical disturbance only the proportion of seabed impacted by the draghead is considered relevant.

The steps taken to prepare AIS data provided by Denmark broadly followed those used by ICES WGEXT (ICES, 2019b). Danish data preparation was carried out in R (versions ranging from 3.6.1 – 4.1.2; R core

team 2019-2021) using the following packages: tidyverse (Wickham et al., 2019), sf (Pebesma, E., 2018), and lubridate (Grolemund & Wickham, 2011). The dataset was first filtered to ensure polylines not indicative of extraction activity were removed where practicable:

- Any polylines that did not intersect with a licensed area were excluded.
- Polylines with start and / or end speeds greater than three knots were removed (not indicative of extraction activity). Polylines with zero knot speeds were retained as these can be indicative of static extraction activity which is present in Danish waters.
- Extraction duration was calculated for each polyline based on the start and end times provided. As recommended via consultation with data providers and experts in Denmark, all lines with a duration of more than one hour were removed to mitigate erroneous lines caused by intermittent AIS data recording.
  - Please see supplementary R scripts for full detail on the methods used.

To enable standardisation of extraction data on a 50 m x 50 m grid (with the aforementioned spatial parameters), the following approach was used to convert AIS polyline data into pressure categories (**Figure A5.1**):

- 1. Line features were spatially intersected with the 50 m x 50 m grid;
- 2. The total length of annual line features within a grid cell were calculated to give a total annual distance of dredge activity within a grid cell;
- 3. The total annual distance of dredge activity within a grid cell was multiplied by draghead width (3 m) to give Swept Area;
- 4. Swept Area Ratio was then calculated by dividing Swept Area by cell area;
- 5. Pressure categories were assigned to the corresponding Swept Area Ratio ranges (Table A5.4).

Please see supplementary R scripts for full detail on the methods used.



Example grid cell:

a) Total length of line features within (50 x 50 m) grid cell = 506.5 m

- b) Multiplied by 3 m draghead width = 1519.5 m<sup>2</sup> (Swept Area)
- c) Divide Swept Area by grid cell area (2500 m<sup>2</sup>) = 0.6078 (Swept Area Ratio)
- d) Assign BH3 pressure category (>0.33 and  $\leq$ 0.66) = 2 (Low)

Figure A5.1: Example of processing AIS line features to calculate Swept Area Ratio and BH3 pressure category.

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## Pressure maps representative of an assessment period

For assessment of disturbance across a time series, 2009 to 2020 (QSR reporting) and 2016 to 2020 (MSFD reporting), representative extraction intensities for the time periods are required. Creating an aggregated pressure score for each assessment period followed the same method described for VMS pressure layers (Annex 4). However, in contrast to the assessment of fishing pressure, grid cells with no extraction pressure present in a given year, where extraction activity was present in other years, were treated as 0 pressure. This specific distinction of 0 pressure was made as commercial aggregate extraction is a licensed activity and, where a Contracting Party submitted data, there was high confidence that the data accounted for all commercial aggregate extraction activity within the Contracting Party's EEZ.

The approach for creating an aggregated extraction pressure map was as follows:

- Combine annual extraction pressure layers: Annual data layers were combined into a single spatial layer using the 'Union' tool in ArcMap v10.1 (ESRI, 2012), or using R (versions ranging from 3.6.1 4.1.2; R core team 2019-2021) using the following packages: tidyverse (Wickham et al., 2019), sf (Pebesma, E., 2018).
- 2) Quantify annual pressure variance across the assessment periods: The variance in pressure within individual grid cells was quantified by calculating the range in SAR categories (Table A5.4) observed across the assessment period. Grid cells with a range in three or more SAR categories were considered to have 'Variable' levels of pressure. Grid cells with a range of less than three SAR categories were considered to have 'Non-variable' level of pressure.
- 3) Calculate final aggregated SAR category for the assessment period: For 'Variable' grid cells, the maximum SAR value was used to assign the BH3 pressure category (Table A5.4). For 'Non-variable' grid cells, the mean SAR value across the assessment period was used to assign the BH3 pressure category.

Please see supplementary R scripts for full detail on the methods used.

# References

Bole, A., Wall, A. & Norris, A. (2014). Chapter 5 - Automatic Identification System (AIS). *Radar and Target Tracking for Professional Mariners, Yachtsmen and Users of Marine Radar.* 3. 255-275.

Boyd, S.E. & Rees, H.L. (2003). An examination of the spatial scale of impact on the marine benthos arising from marine aggregate extraction in the central English Channel. *Estuarine, Coastal and Shelf Science*. Volume 57, Issues 1–2, May 2003, Pages 1-16.

Boyd, S.E., Limpenny, D.S., Rees, H.L., Cooper, K.M. & Campbell, S. (2003). Preliminary observations of the effects of dredging intensity on the re-colonisation of dredged sediments off the southeast coast of England (Area 222). Estuarine, Coastal and Shelf Science. Volume 57, Issues 1–2, May 2003, Pages 209-22.

British Marine Aggregate Producers Association (BMAPA) & The Crown Estate (TCE), 2010 to 2021. Area involved reports – 12<sup>th</sup> to the 23<sup>rd</sup> annual report. [Online] Available at: <u>https://bmapa.org/downloads/reference.php</u> (Accessed September 2022)

British Marine Aggregate Producers Association (BMAPA) & The Crown Estate (TCE), (2010). MarineAggregateTerminology-AGlossary.[Online]Availableat:https://bmapa.org/documents/BMAPA\_Glossary.pdf(Accessed April 2021)

British Marine Aggregate Producers Association (BMAPA) & The Crown Estate (TCE). (2017). The impacts of marine aggregate dredging. *Good Practice Guidance: Extraction by Dredging of Aggregates from England's Seabed.* 9-10. [Online] Available at: https://www.bmapa.org/documents/BMAPA\_TCE\_Good\_Practice\_Guidance\_04.2017.pdf (Accessed April 2021)

Cooper K., Boyd S., Eggleton J., Limpenny D., Rees H. & Vanstaen K., (2007). Recovery of the seabed following marine aggregate dredging on the Hastings Shingle Bank off the southeast coast of England. *Estuarine Coastal and Shelf Science*, 75(4), 547-558.

Cooper K.M., Eggleton J.D., Vize S.J., Vanstaen K., Smith R., Boyd S.E., Ware S., Morris C.D., Curtis, M. I., Limpenny D.S. & Meadows W.J., (2005). Assessment of the re-habilitation of the seabed following marine aggregate dredging-part II. *Cefas Science Series Technical Report No. 130*. Cefas Lowestoft. 82.

Desprez, M. (2000). Physical and biological impact of marine aggregate extraction along the French coast of the Eastern English Channel: short and long-term post-dredging restoration. *ICES Journal of Marine Science*, 57: 1428–1438.

Desprez, M., Stolk, A., & Cooper, K.M. (2022). Marine aggregate extraction and the Marine Strategy Framework Directive: A review of existing research. ICES Cooperative Research Reports, Vol. 354. 64 pp. https://doi.org/10.17895/ices.pub.19248542.

Drabble, R. (2012) Projected entrainment of fish resulting from aggregate dredging. Marine Pollution Bulletin. Volume 64, Issue 2, February 2012, Pages 373-381.

Version 6 October 2022

EMODnet, (2021a). Seabed Habitats. [Online] Available at: https://emodnet.ec.europa.eu/en/seabedhabitats (Accessed: 01/12/2021).

EMODnet, (2021b). Human Activities. [Online] Available at: https://www.emodnethumanactivities.eu/ Accessed: 01/12/2021).

European Environment Agency, (EEA), (2017). EEA marine assessment grid, Jan. 2017. European Geospatial Environment Agency Data Catalogue. [Online] Available at: https://sdi.eea.europa.eu/catalogue/srv/eng/catalog.search#/metadata/84d1f816-1913-45b1-94b7a5721a18296c (Accessed 08/11/2021).

Grolemund, G. & Wickham, H., (2011). Dates and Times Made Easy with lubridate. Journal of Statistical Software, 40(3), 1-25. Available at: https://www.jstatsoft.org/v40/i03/.

Report of the Working Group on Spatial Fisheries Data (WGSFD). ICES (2015). http://www.ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Report/SSGEPI/2015/01 %20WGSFD%20-

%20Report%20of%20the%20Working%20Group%20on%20Spatial%20Fisheries%20Data.pdf

ICES (2016). Effects of extraction of marine sediments on the marine environment 2005–2011. ICES Cooperative Research Report No. 330. 206 pp ISBN 978-87-7482-179-3 ISSN 1017-6195 Available at: https://doi.org/10.17895/ices.pub.5498

ICES (2019a). Workshop to evaluate and test operational assessment of human activities causing physical disturbance and loss to seabed habitats (MSFD D6 C1, C2 and C4) (WKBEDPRES2). ICES Scientific Reports. 1:69. 87 pp. http://doi.org/10.17895/ices.pub.5611

ICES (2019b). Working Group on the Effects of Extraction of Marine Sediments on the Marine Ecosystem (WGEXT). ICES Scientific Reports. 1:87. 133 pp. http://doi.org/10.17895/ices.pub.5733

Kenny, A.J., Rees, H.L. (1994). The effects of marine gravel extraction on the macrobenthos: Early postdredging recolonization. Marine Pollution Bulletin. Volume 28, Issue 7, July 1994, Pages 442-447.

Last, K. S., Hendrick, V. J., Beveridge, C. M., & Davies, A. J. (2011). Measuring the effects of suspended particulate matter and smothering on the behaviour, growth and survival of key species found in areas associated with aggregate dredging. pp. 70

MST (2021). Ministry of Environment of Denmark, extraction sites. [Online] Available at: https://miljoegis.mim.dk/cbkort?profile=miljoegis-raastofferhavet (Accessed 01/12/2021)

Newell, R. C., Seiderer, L. J., & Hitchcock, D. R. (1998). The impact of dredging works on coastal waters: A review of the sensitivity to disturbance and subsequent recovery of biological resources on the seabed. Oceanography and Marine Biology. 36, 127-78.

Newell, R. C., & Woodcock, T. A. (2013). Aggregate dredging and the marine environment: an overview of recent research and current industry practice. The Crown Estate. 165pp ISBN: 978-1-906410-41-4.

OSPAR – Common Biodiversity Indicators: Extent of Physical Disturbance to benthic habitats (BH3) Agreement 2017-09 (Update 2023) CEMP Guidelines – Technical Specifications

Version 6 October 2022

NIBS (2021). Niedersächsischen Bodeninformationssystems Thematic maps, Mining production licences. [Online] Available at: <u>https://nibis.lbeg.de/cardomap3/?lang=en</u> (Accessed 01/12/2021)

Noordzeeloket (2022). Surface Mineral Extraction. [Online] Available at: <u>https://www.noordzeeloket.nl/en/functions-and-use/artikel-baseline/</u> (Accessed 01/02/2022)

OneBenthic database. (2020). Available from https://openscience.cefas.co.uk/OneBenthicExtraction/. Accessed: 01/09/2022.

OSPAR Commission (2009). Summary assessment of sand and gravel extraction in the OSPAR maritime area. Publication number 434/2009. <u>https://www.ospar.org/documents?v=7149</u>

OSPAR Commission (2017a). OSPAR Intermediate Assessment 2017. OSPAR Commission. London.

OSPAR Commission (2017b). OSPAR Coordinated Environmental Monitoring Programme (CEMP) Guidelines. Common Indicator: BH3 Extent of Physical damage to predominant and special habitats (https://www.ospar.org/documents?v=37641).

OSPAR Commission (2019). QSR 2023 Guidance Document. OSPAR Agreement 2019-02. https://www.ospar.org/documents?v=40951

OSPAR Commission, (2021). Feeder Report 2021 – Extraction of non-living Resources. Version 1.0.0. [Online]. Available at: <u>https://oap.ospar.org/en/ospar-assessments/quality-status-reports/qsr-2023/other-assessments/extraction-non-living-resources/</u> (Accessed 28/04/2022)

Pebesma, E. (2018). Simple Features for R: Standardized Support for Spatial Vector Data. *The R Journal* 10 (1), 439-446.

R Core Team (2019). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL <u>https://www.R-project.org//.</u>

R Core Team (2020). R: A language and environment for statistical computing. *R Foundation for Statistical Computing, Vienna, Austria*. Available at <u>https://www.R-project.org/</u>.

R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available at <u>https://www.R-project.org/</u>.

Robson, L.M., Fincham, J., Peckett, F.J., Frost, N., Jackson, C., Carter, A.J., & Matear, L. (2018). UK Marine Pressures-Activities Database "PAD": Methods Report. JNCC Report No. 624, JNCC, Peterborough, ISSN 0963-8091.

The Crown Estate, (2021). Introduction. *Electronic Monitoring System Annual Report 2020*. [Online] Available at: <u>https://www.thecrownestate.co.uk/media/3995/2021-ems-report.pdf</u> (Accessed April 2022)

Tillin, H. M., Houghton, J. Saunders, E., Drabble, R., & Hull, S. C. (2011). Direct and Indirect Impacts of Aggregate Dredging. Science Monograph Series No. 1. Marine ASLF. 41pp.

OSPAR – Common Biodiversity Indicators: Extent of Physical Disturbance to benthic habitats (BH3) Agreement 2017-09 (Update 2023) CEMP Guidelines – Technical Specifications

Version 6 October 2022

ISBN:	978	0	907545	43	9.

Wickham, H., Averick, M., Bryan, J., Chang, W., McGowan, L.D.A., François, R., Grolemund, G., Hayes, A., Henry, L., Hester, J., Kuhn, M., Pedersen, T., Miller, E., Bache, S., Müller, K., Ooms, J., Robinson, D., Seidel, D., Spinu, V., Takahashi, K., Vaughan, D., Wilke, C., Woo, K. and Yutani, H., (2019). Welcome to the tidyverse. *Journal of Open-Source Software*, 4(43), 1686.

# Annex 6 – The Calculation of disturbance values and trend analyses

The degree of disturbance of a habitat is a product of its sensitivity and the exposure to a specific pressure. Information and data on state-pressure impacts are limited to local studies, but the outputs have been used to indicate the amount of change expected if habitats are affected by pressures or if part of the species forming a habitat have been lost (e.g., Rondinini 2010). In order to assess the level of disturbance the linkage of sensitivity information with pressure data is required.

A matrix combining the extent of pressure categories and habitat sensitivity categories supports the classification of ten categories of physical disturbance (Table A6.1). Each category should provide an approximation of the relative impact on the habitat with regard to e.g., habitat structure, species richness, abundance or biomass. For the production of the matrix determining the disturbance categories from pressure and sensitivity classes, the following algorithm was applied:

$$b + \frac{ab}{\overline{b}}$$

a=pressure; b= sensitivity

Dist	urbance	Sensitivity				
m	atrix	1 2 3 4 5				
	Null / 0*	0	0	0	0	0
ω	1	1	2	3	4	6
sure	2	1	2	4	6	7
Les	3	1	3	5	7	9
_ ₽	4	1	4	6	8	9
	5	2	4	7	9	9

Table A6-1. Disturbance matrix combining extent of pressure and habitat sensitivity

The pressure layer (see Annex 4) and the sensitivity layer (see Annex 1) were intersected in ArcGIS v10.1 () using the 'INTERSECT' tool and then the above matrix applied to produce a disturbance category; please see supplementary R script for overview of process used to calculate disturbance. Figure A6.1 shows an example of the procedure and the resulting map with the disturbance categories for the OSPAR common and candidate indicator assessment units.



# **Figure A6-1.** An example of the combination of pressure and sensitivity layers to create a disturbance layer

# Disturbance matrix for the pressure 'abrasion'

Pressure-impact relationships may be described by various types of functions, e.g., linear relation or logarithm function, and depend on the habitat or the life strategy of species. As a first approach to set up a disturbance matrix for the pressure 'abrasion', the modelling results of Schroeder et al. (2008) were used as a basis. Schroeder et al. (2008) modelled fishery-induced mortality rates of selected benthic species with different ecotypes (r- and K-selected species of in- and epifauna) for the fishing gears beam and otter trawl (Figure A6.2).



**Figure A6-2.** Percentage decrease in abundance of the benthic species *Nephtys hombergii, Nucula nitidosa, Crangon crangon* and *Echinus esculentus* induced by beam and otter trawling with different intensities per year (Schroeder *et al.* 2008).

For the development of a disturbance values used in the matrix, the decrease in abundance was averaged over the different species and gears to obtain a logarithmic curve for the physical impact of bottom trawling (Figure A6.3).



**Figure A6-3.** Estimated physical impact on benthic habitats by bottom trawling, based on decrease in abundance modelled by Schroeder et al. (2008).

The values derived from the function were applied to the disturbance matrix combining sensitivity and extent of pressure. Habitat sensitivity was set at intermediate with the respective temporal fishing intensities (e.g. moderate extent of pressure (3) means 100 % of cell fished or 1 fishing event per year) and then extrapolated to the very low and very high categories. The final matrix showing the combination of exposure to the pressure abrasion and sensitivity of habitats is shown in Table A6.2.

**Table A6-2.** Disturbance matrix with the disturbance values taken from Figure A6-3 applied.

```
Disturbance
```

Habitat sensitivity

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matri	x	1	2	3	4	5
	0	0	0	0	0	0
	1	0.5	2	6	29	57
of Ire	2	0.5	2	29	57	65
ent	3	0.5	6	40	65	100
Ext pre	4	0.5	29	57	80	100
	5	2	29	65	100	100

The incorporation of more accurate impacts curves underpinning the calculation of disturbance are current knowledge gaps that will be addressed in future work, through the integration of data and calibration from other indicators using observational or monitoring data (e.g., BH1 pressure-response curves to inform BH3 assessments). Variations driven by biogeographical factors will also be considered as part of the changes to the disturbance matrix. Future improvements using pressure-response curves will facilitate more accurate spatial assessments of impacts through the BH3 calculations particular on areas where little or no monitoring data are available.

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Figure 6-2. Disturbance map produced from the combination of pressure and sensitivity data using the matrix Table A6-1.

#### Aggregating Surface Abrasion Disturbance and Sub-Surface Abrasion Disturbance

Applying the method this far produces a disturbance layer for the pressure 'surface abrasion' and a disturbance layer for 'sub-surface abrasion', which need to be combined into a single disturbance layer. This is done by taking the highest disturbance category per feature. Trend analyses were undertaken on the annual percentage of the assessment unit area under each disturbance group ('High', 'Moderate', 'Low', and 'Zero') across the years of the QSR assessment period (2009 to 2020). Previous assessments categorised disturbance into two categories: 0 to 4, representing lower levels of disturbance; and disturbance categories 5-9, representing higher levels of disturbance. This assessment builds on the existing method by summarising outputs in three distinct groups (alongside 'Zero') to improve resolution of detail and to account for input from experts across the OSPAR Maritime Area (**Table A6.1**). Please note, that these groupings are for communication purposes only, and are not representative of threshold values. The trend analyses were simple line plots produced in R (versions ranging from 3.6.1 - 4.1.2; R core team 2019-2021) using packages tidyverse (Wickham et al., 2019) and sf (Pebesma, E., 2018), over the twelve-year period. Linear regression models had been trialled in the OSPAR Intermediate

Assessment 2017 but were not used due to the small number of data points (trends over 6 years).

Table A6.1 Disturbance matrix with summary groups; 'Zero' (0), 'Low' (1-4), 'Moderate' (5-7), and 'High' (8-9).

Dist	urbance	Sensitivity					
m	atrix	1 2 3 4 5					
	Null / 0*	0	0	0	0	0	
a	1	1	2	3	4	6	
sure	2	1	2	4	6	7	
res	3	1	3	5	7	9	
•	4	1	4	6	8	9	
	5	2	4	7	9	9	

It is important to note that some areas have already lost some of the sensitive species/biotopes due to past human activities, which will result in a lower disturbance score. To address those, the outputs of this indicator will be validated using the assessment results from other benthic condition indicators. It is also expected that during the next MSFD reporting cycle, disturbance matrices and the final algorithm will be calibrated and, if required, modified using the outputs from site-scale condition indicators.

#### Changes made to disturbance layers following expert input

Through consultation with experts through the OSPAR framework, instances where data were thought to be erroneous were highlighted, and changes to the input data were agreed with relevant experts prior to assessments to account for local knowledge. The following changes were made to the final disturbance layers to ensure that outputs were representative and accurate:

#### Swedish No Trawl Zone

Following consultation and review via national experts within the OSPAR framework, areas where initial disturbance outputs were considered erroneous were identified. Within the Norwegian Trench and the Kattegat, the Trålgräns and Fredingsområde Södra Kattegat No Trawl Zones (hereafter referred to as Swedish No Trawl Zone), were identified as areas where trawling was known to be absent between the 2009 to 2020 assessment period. Spatial disturbance outputs in the Kattegat and Norwegian Trench were, therefore, intersected with the boundary of the Swedish No Trawl Zone provided by national experts. Areas within the Swedish No Trawl Zone were then amended to zero disturbance, despite any reported VMS data, to ensure established fisheries management measures were accurately represented. The size of available c-square grid cells and assumed homogeneity of SAR values likely resulted in the erroneous allocation of fishing pressure in areas with established fisheries management measures.

The area of the Swedish No Trawl Zone polygon was then erased from the Norwegian Trench and Kattegat disturbance layers. The amended disturbance layers that had been intersected with the Swedish No Trawl Zone, were then merged with the disturbance layers with the Swedish No Trawl

Zone area erased, to obtain a full coverage disturbance layer, without duplicate polygons, for each of the Norwegian Trench and Kattegat assessment units.

#### North-Iberian Atlantic deep-sea

Areas of deep-sea habitat in the North-Iberian Atlantic contained reported bottom-contacting fishing pressure in locations considered too deep for bottom trawling. National experts highlighted that the presence of VMS data with SAR values in such areas were likely due to vessel speeds slowing for bad weather when in transit across the Bay of Biscay, rather than true fishing activity. Therefore, disturbance values within the Atlantic lower abyssal and Atlantic mid abyssal biological zones (derived from EUSeaMap2021) were amended to zero within the assessment unit, due to high confidence that bottom trawling would not happen in such deep areas of the North-Iberian Atlantic. Conversely, concentrated areas of disturbance recorded in the Atlantic upper abyssal biological zone, around the continental shelf edge, were deemed to be potential fishing activity and therefore, not omitted from analyses.

Atlantic lower abyssal and Atlantic mid abyssal habitats from EUSeaMap2021 were then erased from the original disturbance layer, and the output was then merged with the intersected with the amended disturbance layer obtained from the intersection with Atlantic lower abyssal and Atlantic mid abyssal habitats from EUSeaMap2021.

#### **References:**

Rondinini, C. 2010. Meeting the MPA network design principles of representation and adequacy: developing species-area curves for habitats. JNCC Report No. 439

Schroeder, A., L. Gutow & M. Gusky (2008): FishPact. Auswirkungen von Grundschleppnetzfischereien sowie von Sand- und Kiesabbauvorhaben auf die Meeres-bodenstruktur und das Benthos in den Schutzgebieten der deutschen AWZ der Nordsee (MAR 36032/15). Report for the Federal Agency for Nature Conservation.

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# Annex 7. Development of confidence layers

Input data used to create sensitivity maps in the BH3 indicator (as outlined in Annex 3) relied on the combination of data from a number of different sources, each with associated confidences based on data source and type. The confidence of input data was assessed using categorical scores ('Low', 'Medium', and 'High'), based on the nature of the information, and combined to give an overall confidence score for the assessment period.

## Habitat data: Composite habitat map

Two final confidence values from the composite habitat map were incorporated into the final confidence layers:

- MESH (Mapping European Seabed Habitats) confidence, which assessed the quality of the processes used to create the map (e.g., maps derived from remote sensing and ground-truthing to inform habitat classification were prioritised over modelled data) (Castle et al., 2021).
- Three-step confidence-scoring mechanism to produce a qualitative score (ranging from 0 4), indicative of the likelihood of habitats being mapped correctly within a given study area (please see Lillis (2016) for full detail of the three-step confidence assessment)

For further details on the data sources and confidence assessments used in the creation of the composite habitat map, please refer to Annex 1.

# Sensitivity data

MarESA sensitivity assessments were the predominant source of sensitivity information used in the BH3 assessment. The allocation of confidence scores for MarESA sensitivity assessments were based on the quality of evidence (information sources) used for the resistance and resilience assessments of habitats and species to physical damage pressures (surface abrasion, subsurface abrasion, and extraction). For example, scores derived from experimental, or field survey studies had high confidence, whereas scores based on expert judgment had low confidence (Table 7.1). Areas of deep-sea habitat, that were missing MarESA sensitivity assessments, were assigned sensitivity scores derived from the MB0102 project. However, all habitat sensitivity assessments from MB0102 were given a 'Low' confidence score due to known knowledge gaps in areas of data paucity.

 Table 7.1: MarESA Quality of Evidence scores (Tyler-Walters et. al. 2018)

Confidence level	Quality of evidence (information sources)

Confidence level	Quality of evidence (information sources)
High (H)	Based on peer reviewed papers (observational or experimental) or grey literature reports by established agencies on the feature (habitat, its component species, or species of interest).
Medium (M)	Based on some peer reviewed papers but relies heavily on grey literature or expert judgement on the feature (habitat, its component species, or species of interest) or similar features
Low (L)	Based on expert judgement

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Sensitivity information from *in-situ* species points records also contributed to the confidence of final attributed sensitivity scores. Sensitivity assessments from sample data were included using a precautionary approach and were only assigned to the proportion of habitat polygons that contained the species point record, within relevant grid cells, where they were equal to or greater than the sensitivity value for the underlying habitat.

# Method for the calculation of overall confidence

To calculate an overall numeric confidence score, a method adapted from OSPAR (2015) and OSPAR (2017) was used. The method averaged categorical measures of confidence on a scale of 0 to 1, meaning the final confidence value was the total of four component confidence scores, divided by four to give a final score ranging from 0 to 1.

The four steps below describe how the method for calculating confidence was adapted to develop confidence layers for BH3 bottom-contacting fishing disturbance and aggregate extraction. A numerical score (0.33, 0.66, or 1) was assigned to each of the components used to create the sensitivity layer. A high categorical score of confidence was given a numeric value of 1, a medium categorical score of confidence was given a numeric value of 0.66 and a low categorical score of confidence was given a numeric confidence score was assigned to each of the components associated with the different methods used to create the sensitivity layer:

- Step 1: Confidence in the habitat data (MESH and survey or modelled data)
- Step 2: Confidence in the representativity of the habitat data (Three Step method)
- Step 3: Confidence in the sensitivity assessments (MarESA Quality of Evidence or MB0102)
- Step 4: Confidence from *in-situ* species data

Step 1 – Confidence in the habitat data (MESH and survey or modelled data)

• A confidence value was assigned to the underlying habitat data, as shown in Table 7.2

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Origin of habitat information	Confidence score
Survey map – high confidence	1
(MESH score >80)	
Survey map – low confidence	0.66
(MESH score <80)	
EUSeaMap – high confidence	0.66
(MESH score >80)	
EUSeaMap – low confidence	0.33
(MESH score <80)	

Table 7.2: Numeric confidence score assigned to habitat information.

Step 2 – Confidence in the representativity of the habitat data (Three-Step)

- A confidence score of 1 (High) was assigned where the Three-Step confidence was equal to, or greater than 3.
- A confidence score of 0.66 (Medium) was assigned where the Three Step confidence was 2.
- A confidence score of 0.33 (Low) was assigned where the Three Step confidence was 1.

Step 3 – Confidence in the sensitivity assessments (MarESA Quality of Evidence or MB0102)

- The lowest Quality of Evidence score from the resistance or resilience MarESA sensitivity assessments were assigned for the habitat (please see Annex 2 for details of MarESA assessments). As the BH3 assessment of commercial aggregate activity only assessed one pressure (extraction), and therefore only contained one sensitivity assessment, there was only one lowest Quality of Evidence score. However, for the BH3 assessment of bottom-contact fishing pressures there were two possible lowest Quality of Evidence scores, one for surface and subsurface sensitivity, respectively. Therefore, the following selection process was applied when assessing confidence in the BH3 assessment of bottom-contact fishing:
  - Quality of Evidence scores were used from the sensitivity assessment corresponding to the final disturbance score (i.e., the highest score between surface or subsurface disturbance, assigned following the precautionary principle). For example, if disturbance in the assessment period was derived from surface abrasion, the Quality of Evidence scores were used from the MarESA sensitivity assessments of 'Damage to surface features (e.g., species and physical structures within the habitat)'.
  - Where disturbance was equal for both surface and subsurface abrasion assessments, the highest Quality of Evidence from either assessment was assigned.

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 Where sensitivity assessments were derived from aggregated MarESA assessments (please see Annex 2 for details on aggregated MarESA assessments), Quality of Evidence scores were reduced by one confidence score to account for sensitivity not being a direct assessment (e.g., 'High' Quality of Evidence was assigned 'Medium' confidence).

Step 4 – Confidence from in-situ species data (agreement with habitat assessments).

• Where *in-situ* species sensitivity values from sampled data were equal to or greater than the value derived from the underlying habitat sensitivity assessments, meaning their sensitivity was incorporated in the assessment, a confidence score of 1 (High) was assigned. However, for the BH3 assessment of bottom-contact fishing pressures, *in-situ* species sensitivity scores were only used for the relevant type of disturbance (surface or subsurface). For example, if disturbance was greatest from surface abrasion, 'High' confidence would be assigned if sampled species data had a surface abrasion sensitivity score equal to or greater than the MarESA habitat surface abrasion sensitivity.

The final step combined the aforementioned confidence steps into a final confidence score for the assessment period, and ensured confidence was not overrepresented in areas with limited habitat data.

- Confidence scores (0 to 1) from the four steps were added together and divided by four
- If the final confidence was greater than 'Low' (0.33) in areas mapped at EUNIS level 3 or lower, or in a mosaic habitat (multiple EUNIS codes), final confidence was reduced to 'Low' (0.33).

The method aims to represent the underlying habitat and sensitivity information that was used for disturbance calculations representative of surface or subsurface abrasion (Figure 7.1).

QSR: 2009-2020 Abrasion Sensitivity Confidence 0 い >0 - 0.1 0.1 - 0.2 0.2 - 0.3 0.3 - 0.4 0.4 - 0.5 0.5 - 0.6 0.6 - 0.7 0.7 - 0.8 0.8 - 0.9 0.9 - 1 Outside of Common and Candidate Indicator Assessment Units 1,000 km 0 250 500 750 OSPAR Assessment Units Land

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Figure 7.1: Draft example of confidence map.

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## <u>References</u>

Castle L., Lillis H., Duncan G. & Manca E., 2021. Method for creating a EUNIS level 3 seabed habitat map integrating fine- and broad-scale maps for the North-East Atlantic. JNCC report in Prep.

Lillis, H., (2016), A three-step confidence assessment framework for classified seabed maps, JNCC Report No. 591, JNCC, Peterborough, ISSN 0963-8091.

OSPAR (2015). Confidence and Uncertainty in assessing cumulative effects. Presented at the OSPAR Meeting of the Intercessional Correspondence Group on Cumulative Effects, ljmuiden (NL): 26-27 Feb 2015 "Bringing it all together".

OSPAR Commission, 2017. OSPAR Coordinated Environmental Monitoring Programme (CEMP) Guidelines. Common Indicator: BH3 Extent of Physical damage to predominant and special habitats (https://www.ospar.org/documents?v=37641).

Tillin, H.M., S.C. Hull & H. Tyler-Walters (2010): Development of a Sensitivity Matrix (pressures-MCZ/MPA features). Defra Contract No. MB0102 Task 3A, Report No. 22. http://jncc.defra.gov.uk/pdf/MB0102\_Sensitivity\_Assessment%5B1%5D.pdf

Tillin, H. & Tyler-Walters, H., (2014): Assessing the sensitivity of subtidal sedimentary habitats to pressures associated with marine activities - Phase 1 Report, JNCC Report 512A. http://jncc.defra.gov.uk/page-6790

Tillin, H.M. & Tyler-Walters, H. (2015). Finalised list of definitions of pressures and benchmarks for sensitivity assessment. 7-9.

Tyler-Walters, H., Tillin, H.M., d'Avack, E.A.S., Perry, F. & Stamp, T., 2018. Marine Evidence based Sensitivity Assessment (MarESA) – A Guide. Plymouth: Marine Biological Association. Zacharias, M. A. & Gregr, E. J. (2005). Sensitivity and Vulnerability in Marine Environments: an Approach to Identifying Vulnerable Marine Areas. *Conservation Biology.* 19, 86-97.